PB87-140331

Metallurgical Coke Industry Particulate Emissions Source Category Report

GCA Corp., Bedford, MA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Dec 86

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA/600/7-86/050	2.	3. RECIPIENT'S ACCESSION NO. PB87 140331/AS
4. TITLE AND SUBTITLE Metallurgical Coke Industry Particulate Emissions: Source Category Report		5. REPORT DATE December 1986 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John Fitzgerald, John Jeffery, and Paul Wolf		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA/Technology Division 213 Burlington Road Bedford, Massachusetts 01730		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-3157, Task 19
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Task Final; 6/83 - 8/86 14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Dale L. Harmon, Mail Drop 61, 919/541-2429.

16. ABSTRACT The report gives results of a study to develop particulate emission factors based on cutoff size for inhalable particles for the metallurgical coke industry. After a review of available information characterizing particulate emissions from metallurgical coke plants, the data were summarized and rated in terms of reliability. Size specific emission factors were developed from these data for the major processes used in the manufacture of metallurgical coke. A detailed process description is presented with emphasis on factors affecting the generation of emissions. A replacement for Section 7.2 (Coke Manufacturing) of EPA report AP-42, A Compilation of Air Pollutant Emissions Factors, was prepared, containing the size specific emission factors developed during this program.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Coke Metallurgical Fuels Particles Emission	Pollution Control Stationary Sources Emission Factors Particulate Inhalable Particles	13B 21D 14G
18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified 20. SECURITY CLASS (This page) Unclassified	21. NO. OF PAGES 96 22. PRICE

EPA Form 2220-1 (9-73)

EPA/600/7-86/050
December 1986

PB87-140331

METALLURGICAL COKE INDUSTRY PARTICULATE EMISSIONS: SOURCE CATEGORY REPORT

by

John Fitzgerald
John Jeffery
Paul Wolf

GCA CORPORATION
GCA TECHNOLOGY DIVISION, INC.
Bedford, Massachusetts 01730

EPA Contract No. 68-02-3157
Technical Directive 19

EPA Project Officer: Dale L. Harmon
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The objective of this study was to develop particulate emission factors based on cutoff size for inhalable particles for the metallurgical coke industry. After review of available information characterizing particulate emissions from metallurgical coke plants, the data were summarized and rated in terms of reliability. Size specific emission factors were developed from these data for the major processes used in the manufacture of metallurgical coke. A detailed process description was presented with emphasis on factors affecting the generation of emissions. A replacement for Section 7.2 (Coke Manufacturing) of EPA report AP-42, A Compilation of Air Pollutant Emissions Factors, was prepared, containing the size specific emission factors developed during this program.

CONTENTS

Abstract iii
Figures vi
Tables viii

1. Introduction 1
   Program Objective 1
   Methodology 1
2. Industry Description 3
   Introduction 3
   Coal Preparation 5
   Wet Coal Charging 8
   Coal Preheating and Charging 10
   Coke Oven Underfiring 11
   Topside Emissions: Charge Port Lids and Offtakes . . . 12
   Door Emissions 14
   Pushing 15
   Quenching 16
   Coke Handling 18
   References 20
3. Metallurgical Coke Emission Factors 21
   Total and Size-Specific Emission Factors 21
   Data Review Procedures 21
   Summary of Test Data 54
   References 57
4. Proposed AP-42 Section for Metallurgical Coke Manufacturing . 63

FIGURES

Number		Page
1	Metallurgical coke production in the U.S.	4
2	Flow sheet showing the major steps involved in the carbonization of coal by the byproduct process	6
3	Schematic of a diagram of byproduct coke oven battery showing major emission sources	7
4	Generalized coal-handling system.	9
5	Cross-section view of a typical offtake and collector main.	13
6	Schematic diagram of a wet quench tower	17
7	Generalized coke handling system.	19
8	Coal preheating (uncontrolled).	42
9	Coal preheating (controlled with scrubber).	43
10	Coal charging (sequential) average of 2 tests	44
11	Combustion stacks (uncontrolled) average of 3 sites	45
12	Pushing (uncontrolled) average of 6 sites	46
13	Pushing (controlled with scrubber) average of two sites. . .	47
14	Mobile scrubber cars	48
15	Quenching (uncontrolled) dirty water >5,000 mg/1 TDS	49
16	Quenching (uncontrolled) clean water <1,500 mg/1 TDS	50
17	Quenching (controlled with baffles)--dirty water >5000 mg/1 TDS	51
18	Quenching (controlled with baffles)--clean water < 1,500 mg/1 TDS.	52

FIGURES (continued)

Number		Page
7.2-1	The major steps in the carbonization of coal with the byproduct process.	65
7.2-2	Byproduct coke oven battery, with major emission points shown	67
7.2-3	Coal preheating (uncontrolled)	73
7.2-4	Coal preheating (controlled with scrubber)	74
7.2-5	Coal charging (sequential) average of 2 tests	75
7.2-6	Pushing (uncontrolled) average of 6 sites	76
7.2-7	Pushing (controlled with scrubber) average of 2 sites . . .	77
7.2-8	Mobile scrubber cars	78
7.2-9	Quenching (uncontrolled) dirty water >5,000 mg/L TDS	79
7.2-10	Quenching (uncontrolled) clean water <1,500 mg/L TDS	80
7.2-11	Quenching (controlled with baffles) dirty water >5,000 mg/L TDS	81
7.2-12	Quenching (controlled with baffles) clean water <1,500 mg/L TDS	82
7.2-13	Combustion stacks (uncontrolled) average of 3 sites	83

TABLES

Number		Page
1	Emission Factors for Coke Manufacturing.	22
2	Size Specific Emission Factors for Coke Manufacturing	24
3	Source Emission Factors: Coal Crushing--With Cyclone	27
4	Source Emission Factors: Preheaters--Uncontrolled	27
5	Source Emission Factors: Preheater--With Scrubber	28
6	Source Emission Factors: Preheaters--With Wet ESPs	29
7	Source Emission Factors: Charging--Uncontrolled	29
8	Source Emission Factors: Charging--Sequential	30
9	Source Emission Factors: Charging--Scrubber on Larry Cars . .	30
10	Source Emission Factors: COG Underfiring--Uncontrolled . . .	31
11	Source Emission Factors: BFG Underfiring--Uncontrolled. . . .	32
12	Source Emission Factors: COG Underfiring--With ESP	32
13	Source Emission Factors: COG Underfiring-With Baghouse . . .	33
14	Source Emission Factors: Pushing--Uncontrolled.	34
15	Source Emission Factors: Pushing--With Wet ESP.	35
16	Source Emission Factors: Pushing--With Venturi Scrubber . . .	35
17	Source Emission Factors: Pushing--With Baghouse	36
18	Source Emission Factors: Pushing--With Mobile Scrubber Car. .	37
19	Source Emission Factors: Door Leaks-Uncontrolled.	39

TABLES (continued)

Number		Page
20	Source Emission Factors: Quenching--Clean Water Uncontrolled.	39
21	Source Emission Factors: Quenching--Dirty Water Uncontrolled.	39
22	Source Emission Factors: Quenching-- Clean Water With Baffles	40
23	Source Emission Factors: Quenching--Dirty Water With Baffles.	40
24	Source Emission Factors: Coke Handling--With Cyclone.	41
7.2-1	Emission Factors for Coke Manufacturing	69
7.2-2	Size Specific Emission Factors for Coke Manufacturing	71

SECTION 1

INTRODUCTION

PROGRAM OBJECTIVE

This program was designed to summarize the best available information on particulate matter emissions in the Metallurgical Coke Manufacturing industry. The program objective was to develop reliable total and size specific emission factors and prepare an update of Section 7.2, Coke Manufacturing, in AP-42: "A Compilation of Emission Factors." AP-42 was last revised in October 1980 for this source category.

METHODOLOGY

An intensive literature search was conducted to obtain all available stack test reports and results. The obtained particulate and particle size emissions data were reviewed, analyzed, summarized and ranked according to the criteria provided in the report "Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections," April 1980. Data used to develop the October 1980 AP-42 Section, as well as newer data were compiled. Since the objective of this AP-42 update required technically-sound, well-documented stack test results, the data were rated as follows:

- A = Tests performed by a sound methodology and reported with enough detail and documentation for adequate validation. These tests are not necessarily EPA reference method tests, although such reference methods are preferred and used as a guide.

- B = Tests that were performed by a generally sound methodology, but lack enough detail and documentation for adequate validation.

- C = Tests based on an untested or new methodology or that lack a significant amount of background data.

- D = Tests based on a generally unacceptable method, but may provide an order-of-magnitude estimate for the emission source.

After ranking the obtained data, AP-42 emission factors were calculated using the highest quality data available. The quality of the data used to develop each emission factor is indicated by the emission factor rating. The following ratings were applied to each emission factor.

- A = Excellent--Developed from A-rated test data taken from many randomly chosen facilities in the industry population. This source category* is specific enough to minimize variability within the source category population.

- B = Above Average--Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As with the A rating, the source category is specific enough to minimize variability within the source category population.

- C = Average--Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As with the A rating, the source category is specific enough to minimize variability within the source category population.

- D = Below Average--The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are footnoted in the emission factor table.

- E = Poor--The emission factor was developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always footnoted.

Process and control descriptive data, and general industry information were obtained, summarized, and presented as general background information. It was not the objective of this program to provide detailed engineering analyses, product specifications, or detailed evaluations of trends in the industry.

This report is structured according to the "Outline for Source Category Reports" which was included in the technical directive to conduct this program. There is necessary duplication of information between Section 4, the proposed AP-42 section, and Sections 1 through 3 of the report in order that the proposed Section 4 can stand alone once inserted into AP-42.

No environmental measurements were conducted during this program, therefore, no separate QA section is contained in this report. The quality of the existing data has been evaluated as described above.

---

*Source category: A category in the emission factor table for which an emission factor has been calculated; generally a single process.

SECTION 2

INDUSTRY DESCRIPTION

INTRODUCTION

The domestic metallurgical coke manufacturing industry currently consists of 40 operative production facilities commonly referred to as coke plants. Each coke plant consists of one or more coke oven batteries. Each battery contains between 10 and 100 individual, slot-type ovens, also called coking chambers. The battery is arranged by alternating the ovens with heating flues. The purpose of the coking operation is to drive off the volatile matter in coal by thermal distillation to form the carbonaceous residue called coke. The volatile matter is collected from each oven and piped to an adjacent "byproduct recovery plant" for recovery of coal byproducts, including coke oven gas which is returned to heat the ovens.

Metallurgical coke refers to coke used to produce molten iron from iron ore in the blast furnace. Also termed "blast furnace" or simply "furnace" coke, metallurgical coke has been defined as a strong and porous carbonaceous residue resulting from high temperature distillation of select grades of bituminous coal.[1]

By varying oven operating parameters and coal type, another form of coke termed foundry coke can be made. Foundry coke, used in cupola furnaces to melt iron in a foundry, accounts for a small percentage of domestic coke production. This source category report focuses on metallurgical coke production. However, for many coke oven emission sources, there may be little difference between foundry and metallurgical coke plants.

Figure 1 describes total domestic production of metallurgical coke for 1962 to 1981. The decline in production reflects reduced demand for domestic iron and steel products, and the closing of many coke plants over the past 10 years.

The major processes involved in coke production by the byproduct method are:

1. Coal preparation and handling;

2. Preheating, if used;

3. Coal charging;

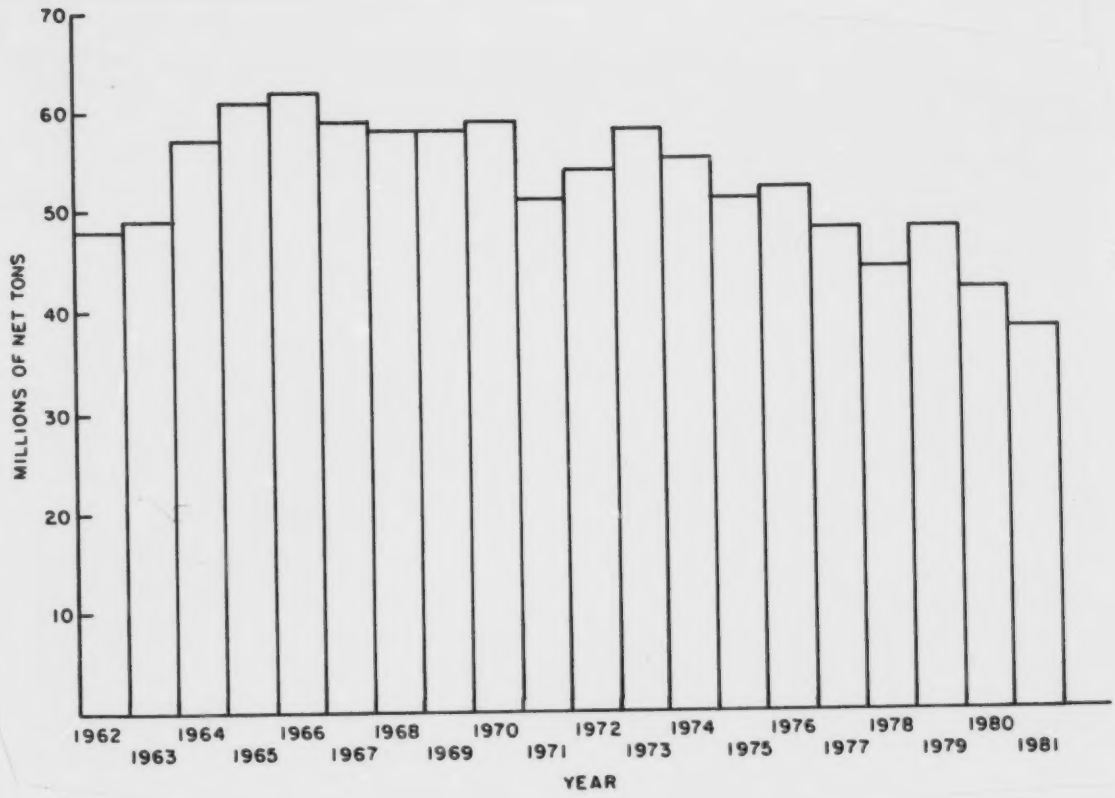


Figure 1. Metallurgical coke production in the U.S. (tons x 10^6).[1,10,11]

4. Coke oven underfiring and coking;

5. Coke pushing;

6. Coke quenching; and

7. Coke handling.

The specific emission sources related to each process will be discussed in this section. A flow diagram representing the major and minor processes in coke manufacture is presented in Figure 2. A schematic showing the major emission sources from byproduct coke ovens is given in Figure 3. This program focused on the batteries, not the byproduct recovery plant.

The individual byproduct ovens consist of three main parts, the coking chamber, heating chamber and regenerative chamber. These are all lined with refractory brick. The coking chamber dimensions for different types of ovens vary from 30 to 43 feet long, 9 to 20 feet high, and 12 to 22 inches wide.[2] The ovens are arranged side by side. A heating chamber is located between each coking chamber. The regenerative chambers for heat recovery from combustion gases are underneath the coking and heating chambers.

The coal is crushed, blended and charged into the hot ovens. The coal can be charged either wet or dry. Wet coal is usually charged by a larry car, whereas dry or preheated coal is charged by a larry car, by a pipeline, or by a conveyor system. After charging, the coal is heated for a predetermined time, typically ranging from 12 to 18 hours under normal production conditions. During the coking cycle, volatile components driven from the coal are collected through offtakes located at the ends of the ovens. The gases pass into a collector main which transports the coke oven gas to a byproduct plant for recovery of gas and chemicals. At the end of the coking cycle, vertical doors located at each end of an oven are removed. The coke is pushed from the oven into a hot-coke, or quench, car located on rails along the battery side. The quench car carries incandescent coke to a quench tower where water is sprayed on the coke to rapidly cool it. The quenched coke is then transferred to the coke wharf for further cooling, then transferred by conveyors to a screening station for removal of fines (coke breeze). Details of each production step appear below.

COAL PREPARATION

Before coal is charged to the ovens, it is typically pulverized so that 80 to 90 percent of the coal is of a size less than 1/8 in. Usually, two or more types of coal (low, medium and high volatile) are blended to produce the desired coal qualities. Blending of coals improves byproduct quality, and extends life of coke oven walls by avoiding excessive pressure on the walls caused by expansion of the coal.

After the pulverized coal is mixed and blended, water or oil may be added to adjust the coal's bulk density. The blended coal mixture is then transported to storage bunkers on the battery prior to charging.

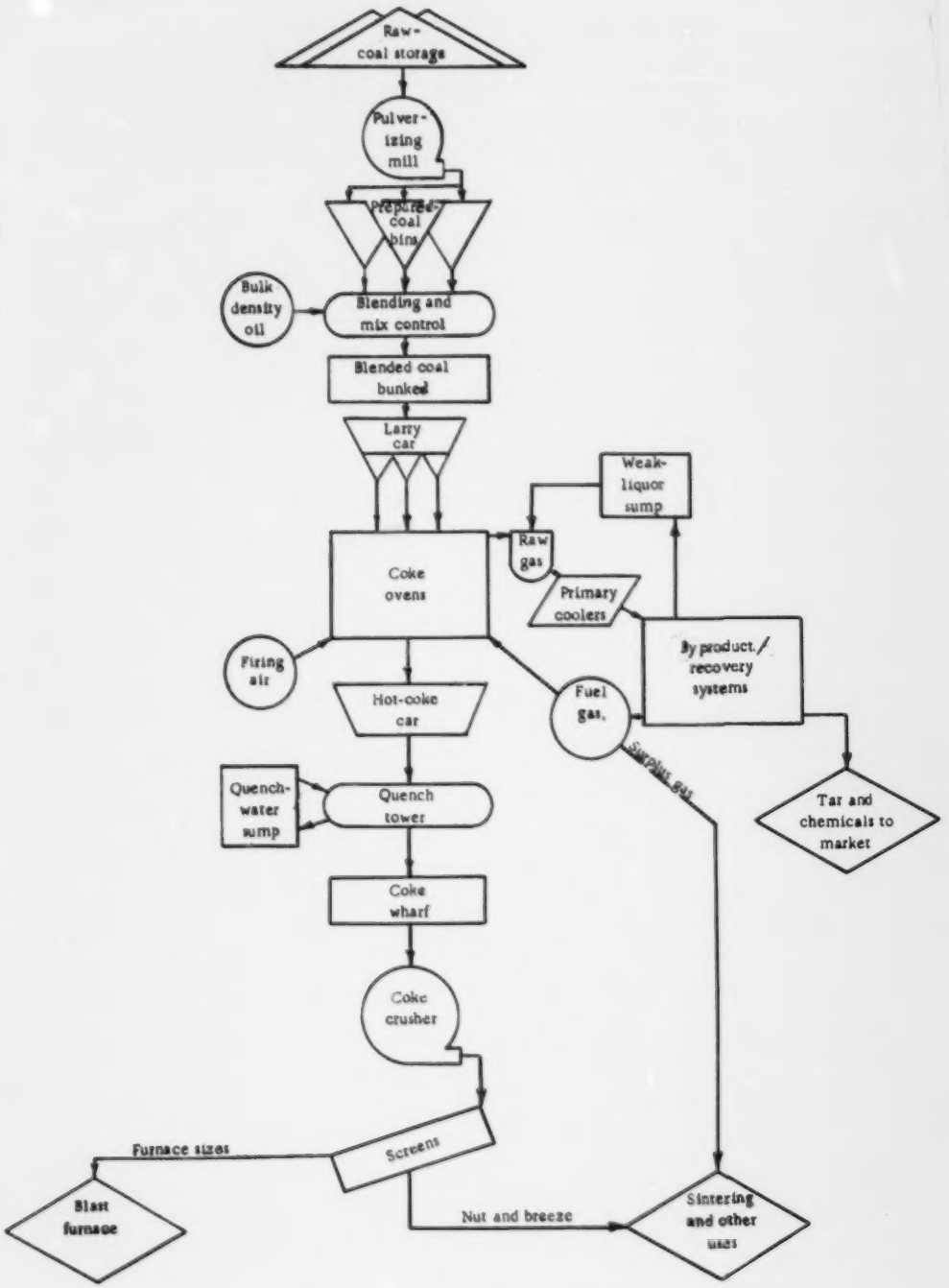


Figure 2. Flow sheet showing the major steps involved in the carbonization (coking) of coal by the byproduct process.[1]

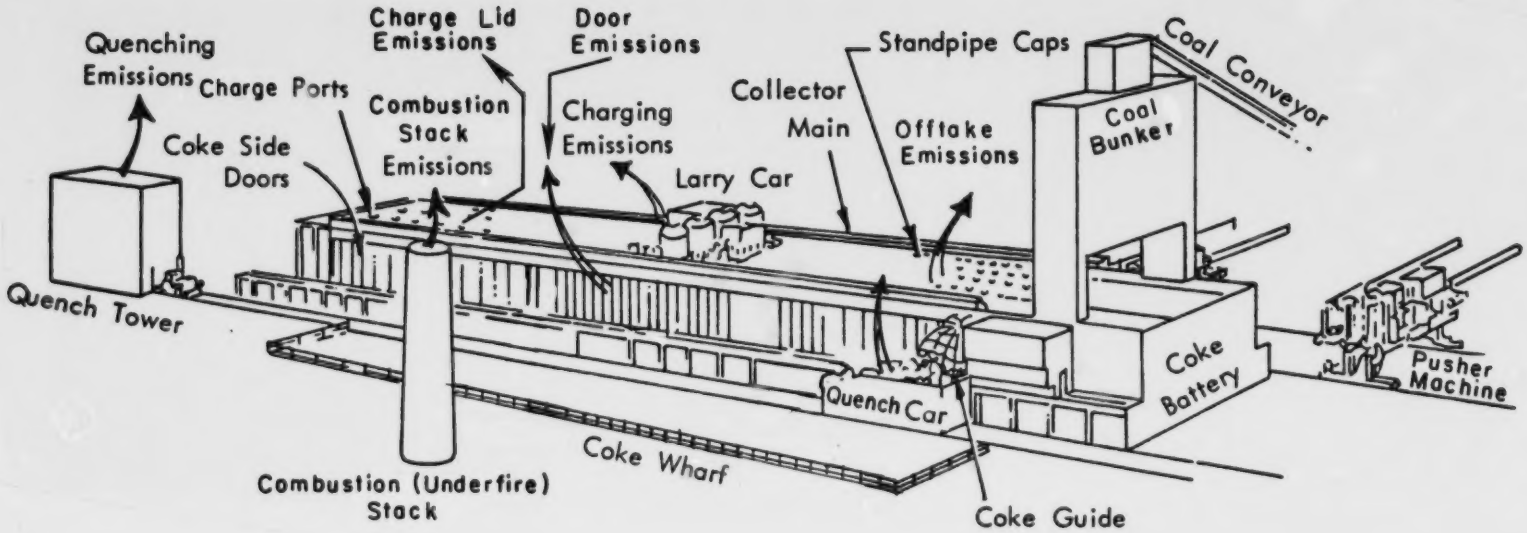


Figure 3. Schematic of a diagram of byproduct coke oven battery showing major emission sources.[4]

Particulate emissions are generated during coal preparation operations primarily during coal crushing (pulverizing). Coal pulverization usually occurs in an enclosed area, and most of the emissions are contained. Minor fugitive emissions occur when transferring coal from conveyor to conveyor, or conveyor to the coal bunker. A flow-diagram of a typical coal handling system is shown in Figure 4.

WET COAL CHARGING

After the coal is pulverized and blended, if it is not preheated, it is charged directly into the coke ovens at ambient temperature. The blended coal is usually transported by conveyor belts to large coal bunkers located on top of the coke oven battery. A large rail-type vehicle, called a larry car, receives a weighed or volume-measured amount of coal from the coal bunker. The coal is gravity-fed into three or four vertical hoppers mounted on the larry car. The larry car then travels over the top of the coke oven battery until reaching the oven to be charged. The larry car is aligned over charging ports located in the oven top. Telescoping drop sleeves connect each of the coal hoppers with its respective charging port. The coal is charged to the oven in accordance with carefully-established procedures designed to minimize emissions. Coal feed into the ovens is accomplished either by gravity, screwfeed, or turntable mechanisms on the larry car. A leveler bar located on the push machine is used to level the coal distribution in the oven during the end of the charge. The leveler bar is inserted through a small "chuck door" located within the oven door. The leveler bar moves back and forth, leveling the coal in the oven. The chuck door and charging lids are then sealed and the coking cycle begins.

Wet coal charging is considered a significant source of emissions at a coke plant, if not controlled. When the coal enters the oven, a large volume of steam, gas and smoke are generated and can escape to the atmosphere if not controlled. The steam evolves from the moisture in the coal, while the gases and smoke result from the evolution of volatile constituents in the coal. There are also significant amounts of particulate matter generated during the charging sequence.

Two similar techniques for charging wet coal are used in the industry to control emissions resulting from charging. Stage charging was developed in England in the 1950s and later applied in the United States.[3] In this process, coal is charged from the larry car hoppers into an oven in a predetermined sequence. The oven is placed under negative pressure by using a steam ejector (aspirator nozzle) located within the gooseneck of the ascension pipe (standpipe) which connects the oven to the collector main. Negative pressure is maintained in the oven during charging to prevent smoke or gas leakage from the charging ports or larry car. Thus, charging emissions can be drawn into the battery collector main and sent to the byproduct recovery plant.

Effective stage charging requires clean (unobstructed) ascension pipe and gooseneck gas passages. These are areas where carbon deposits build up and, therefore, must be cleaned frequently.

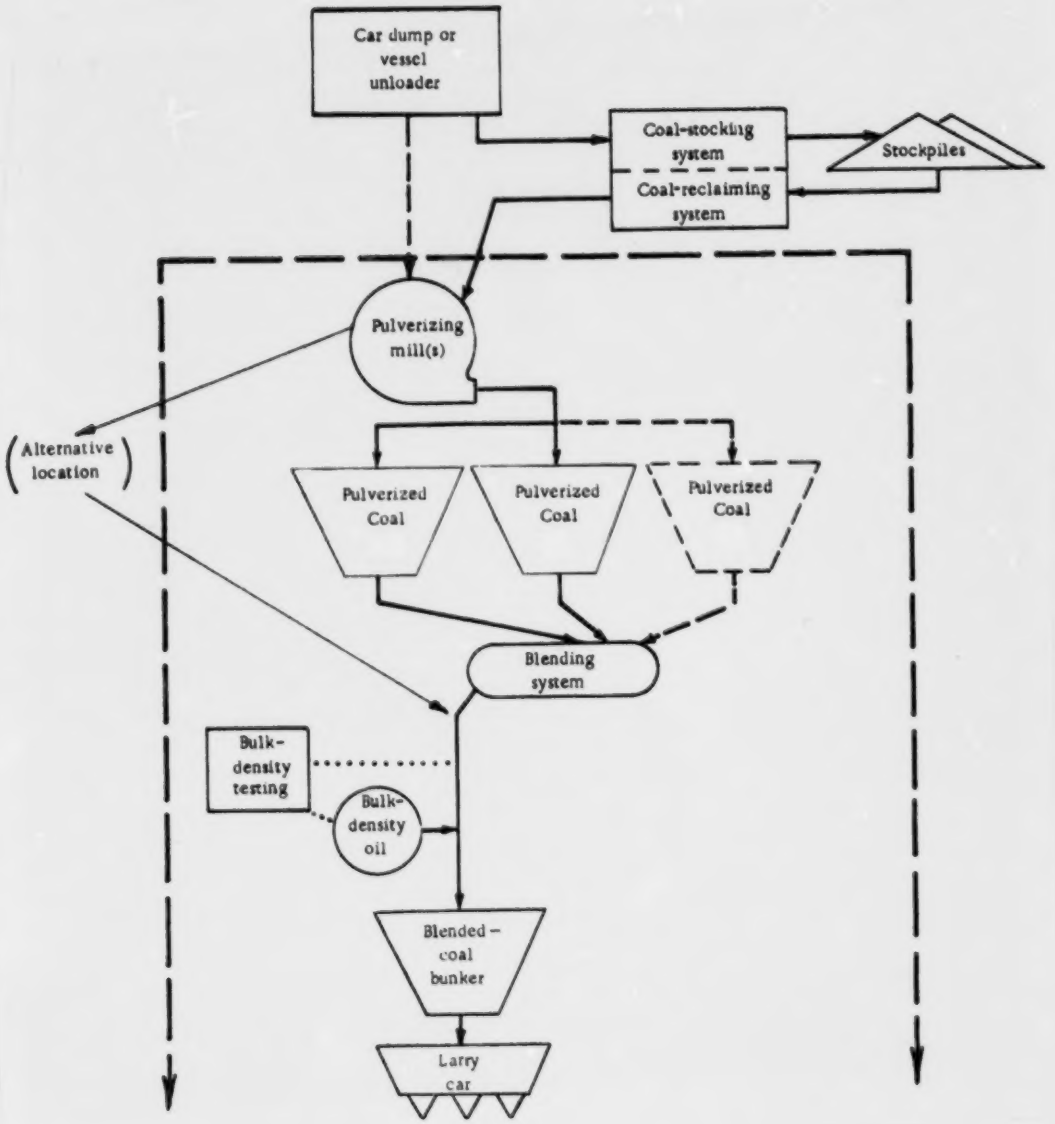


Figure 4. Generalized coal-handling system.[1]

Sequential charging is very similar to stage charging. The oven is also maintained under negative pressure by steam aspiration. The main objectives accomplished by sequential charging are shorter charge times and a more level charge within the oven. Usually, in an oven with four charging ports, the two outside ports are charged together, then the third port is charged, and then the last port is charged. Leveling normally occurs as the last hopper is completing its discharge.

A third type of system, used infrequently to control charging emissions, is a scrubber system mounted on the larry car. The scrubber system captures emissions from the charging sleeves of the larry car. Some of the volatile emissions are spontaneously ignited at the base of the charging sleeve. The remaining emissions enter the scrubber for conventional gas cleaning. When the larry car returns to the coal bunker for another load of coal, dirty scrubber water is discharged and clean water is taken aboard.

COAL PREHEATING AND CHARGING

Coal preheating is a process of flash drying pulverized coal to remove moisture. The process was installed on several batteries, in the 1970s, representing about 10 percent of the U.S. coke production capacity. The preheat operation consists of a two-step process. The first step is the actual heating and drying of the coal; the second is the charging of the hot coal into the ovens.

Pulverized coal is heated in a vertical, fluidized preheating column to temperatures of 400° to 500°F by combustion of natural or coke oven gas. The flash-dried coal is carried up the column with the hot combustion gases and separated from the gas stream by a series of primary and secondary cyclones. Some preheating systems use a two-stage drying process.

Three types of systems have been used to charge preheated coal in the U.S.: pipeline, conveyor, and hot larry. The pipeline system is completely enclosed, transporting coal via a pipeline into the ovens. The method of coal transport is usually super-heated steam. The conveyor method is a two-step process. The hot coal is initially transported by a chain conveyor into a series of weigh hoppers. From the hoppers, coal travels along the battery via conveyors to a charging buggy similar to a conventional larry car where it is gravity fed into the ovens.

The hot larry car method of charging preheated coal is similar to conventional charging. The hot coal is discharged from feed bunkers into the larry car. The larry car travels to the oven to be charged and is aligned over the charging ports. Due to the fluid properties of preheated coal, a leveler bar may be unnecessary when using either of the three dry coal charging methods.

The main advantages of dry coal charging are: lower grade coals can often be used for coking; coking times are reduced and battery production is increased; the coke produced is of better quality (for a given coal quality); and the coking temperature in the oven is more uniform. The disadvantages of

preheating coal are: more coal fines are introduced to the byproduct gas; increased production complexity associated with the preheating facility; and additional facilities for coal handling and transport are required.

Preheater emissions are controlled by conventional gas cleaning devices, either venturi scrubbers or electrostatic precipitators. Leaks occasionally occur from pipeline charging systems due to the positive pressure exerted in the ovens which forces emissions out through charge lids and oven doors. Conveyor and hot larry car charging have emission problems similar to conventional wet coal charging.

COKE OVEN UNDERFIRING

After charging into the ovens, coal is heated to high temperatures, typically in excess of 2,000°F. The heat is provided to the coal mass by burning fuel in long flues located between each oven. Each series of flues heat one wall of the two adjacent ovens.

There are two main types of underfiring systems: underjet and gun flue. The underjet system utilizes vertical gas lines with orifices in the line to feed fuel to the flue. The gun flue system utilizes a horizontal header between each set of ovens, containing a series of combustion nozzles. The fuel flows through the header to the nozzles at the bottom of the flue. There are no fans used on combustion stacks unless a gas cleaner is used. The ovens are operated during the coking process under a positive pressure, while the flues are operated near or below atmospheric pressure.

Two fuels are commonly used for coke oven heating: blast furnace gas (BFG) and/or coke oven gas (COG). Natural gas is rarely used, usually for heating the battery during plant startup, or unusual conditions. COG is used much more frequently than BFG. The coking process produces approximately 10,800 scf of COG per ton of coal charged. Approximately 5,700 scf per ton of coal is required to provide the heat needed for the coking process. Raw COG is drawn from each oven into the collector mains, located on top of the coke battery, and sent to the byproducts plant where it is cleaned of coal byproducts including tars, ammonia and light oils. Sulfur compounds are removed from the cleaned COG in some plants, prior to combustion in the oven flues. The COG normally contains over 50 percent hydrogen and 25 percent methane, and has a heating value of 500 to 550 Btu/scf.[4] BFG is a cleaner gas with a typical heating value of 80 Btu/scf. The main advantage of BFG is that it has a much lower sulfur content than nondesulfurized COG.

There are two sources of particulate emissions from coke battery combustion stacks: improper combustion of fuel, and oven-to-flue leakage. Improper combustion occurs when excess fuel leaks into the flue or the regenerator chambers, causing a fuel-rich condition. Oven-to-flue leakage occurs when coal fines and coal decomposition gases escape into the flues through cracks in the brickwork between the oven and flue.

Sulfur emissions from coke battery combustion stacks result from the sulfur content of coke oven gas. Sulfur emissions are usually in the form of hydrogen sulfide (H_2S) which can be stripped from the COG using desulfurization techniques. Blast furnace gas and natural gas do not pose a similar problem because of lower sulfur contents.

The control of coke battery combustion stack emissions is complicated by the fine particle size, low density and low grain loading of the emissions. A common control technique is routine oven patching in order to seal cracks in the walls between the flues and ovens.

Conventional gas cleaning devices, including ESPs and fabric filters, have been installed on battery stacks. Dry electrostatic precipitators (ESPs) have been installed, with mass collection efficiency ratings ranging from 24 to 90 percent.[4] The collection efficiency is dependent on the inlet grain loading. The advantages of the dry ESP are its low operating cost, low pressure drop, and system reliability. The disadvantages are its large physical size, high capital cost, and dust disposal requirements.

Fabric filters (baghouses) have been installed to control several coke oven combustion stacks. One installation has shown a collection efficiency of 40 to 60 percent on condensible matter, and 40 to 90 percent on total particulate matter.[4] The mass efficiency of front-half catches ranged from 40 to 99.7 percent, and averaged around 90 percent.

TOPSIDE EMISSIONS: CHARGE PORT LIDS AND OFFTAKES

Emissions from charge port lids and oven offtake piping are commonly termed "topside emissions" since they occur on top of the battery. The charge port lids cover the oven charge holes during the coking cycle, and are removed prior to a charge. Domestic batteries have between three and five charge lids per oven. After the charge, the lids are immediately replaced onto the charge port and manually sealed with a sealant mixture termed "luting material" or simply, "mud." Coal decomposition products can leak through the charge lid seal during coking if the seal is inadequate or is disturbed. Charge lid emissions are negligible in a battery with good operating practices and diligent work crews.

A typical offtake is illustrated in Figure 5, showing the vertical standpipe (or ascension pipe); the covered "gooseneck"; the cap (or lid); and connecting flanges. Also shown is the typical location of the steam nozzle for oven aspiration during charging. The gooseneck is continually sprayed with "flushing liquor" to keep it cool. Flushing liquor is one of the products of the byproduct recovery plant. Also shown in Figure 5 is the damper used to isolate the oven from the collector main during pushing and decarbonizing operations (described later). Each oven has either one offtake (i.e., a "single collector main" battery) located at either the push side or the coke side; or two offtakes, one at each end of the oven (i.e., "double collector main" battery).

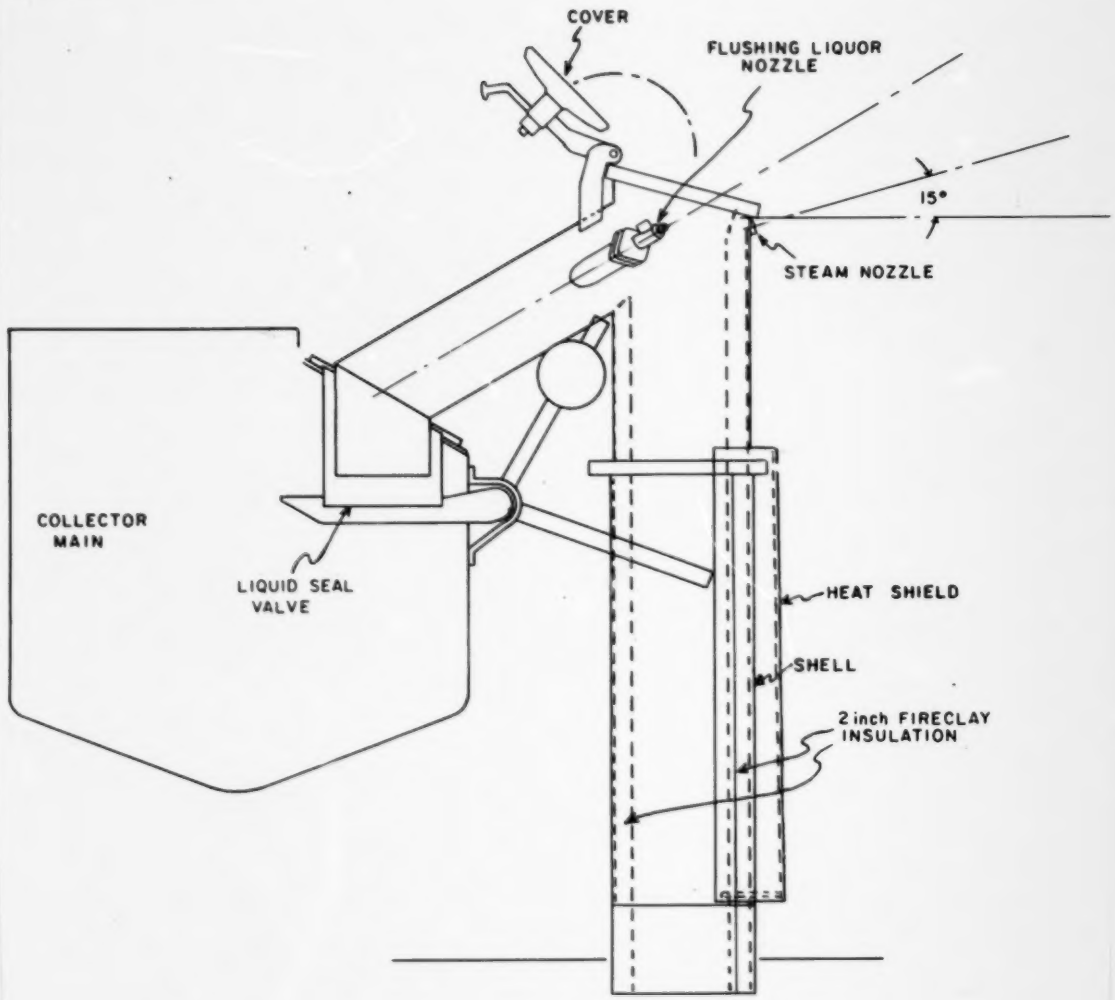


Figure 5. Cross-section of typical offtake and collector main.

Offtake emissions may result from three phases of coke oven operations, i.e.:

- Intentional generation of emissions during "decarbonizing periods." After each push, the standpipe cap and one or more charge lids are usually left open prior to the next coal charge to burn off carbon accumulations on interior surfaces of the oven and offtake piping;

- Pushing emissions- standpipe caps are normally left open during a push, producing a brief emission of coke fines and combustion productions from coke oven gas. One or more charge lids may also be removed during the push; and

- Leakage of coke oven gas and coal decomposition products during the coking cycle, through leaks or cracks in flanges, the cap or other portions of the offtake (charging emissions can also leak through damaged offtakes).

Control of offtake leaks requires routine and diligent work practices consisting of patching and replacement of leaking offtake components. No controls are applied to offtake emissions during decarbonizing periods and pushing. Charge port and offtake emission rates have not been measured due to their intermittent, fugitive nature.

DOOR EMISSIONS

The vertical doors on the coke side and push side of each oven range in height from 3-meters (i.e., a "3-meter" battery) to 6-meters (i.e., a "6-meter", or "tall" battery). The doors are removed by the oven machinery prior to the pushing operation. The door-to-oven sealing surfaces are cleaned of carbon deposits either manually or automatically with scraper blades and tools. Doors are then replaced prior to the charge, and remain in place until the next push.

Door emissions can occur throughout the coking cycle if the door does not effectively seal the oven from the ambient air. The oven operates under slight positive pressure during coking to prevent entry of oxygen from ambient air into the oven. Therefore, coke oven gas and coal decomposition products will leak through the door seal if effective seals are not maintained.

Control of door emissions is a complex problem requiring meticulous attention to: (a) door and oven jamb cleaning; (b) frequent door maintenance, adjustment, and replacement; (c) maintenance of oven jambs; and (d) effective worker performance and supervision. Most coke oven doors are classified as a "self-sealing" design. This design relies on tars from the door leakage to quickly seal small gaps between the door sealing ring (or "knife" edge) and the door jamb attached to the oven face. Hence, doors sometimes leak for an hour or less after the charge, before the sealing process is complete. Where gaps between the knife edge and door jamb are large enough, the door continues to leak emissions during the entire coking cycle.

Some metallurgical coke plants spray or hand-apply a sealant material to the perimeter of the door to provide a positive seal. If the doors and jambs are in good condition, this practice is usually unnecessary. Some older batteries do not have self-sealing doors, and rely on hand-applied sealants to control door emissions.

The number of doors leaking, and the emission rate of each leaking door is highly variable between different batteries. The extent of door leaks depends primarily on the physical condition of the doors and jambs, and the specific plant's attention to door leak control. Only a few mass emissions measurements have been made for door leaks using a temporary collection hood, or a coke-side shed installed primarily for pushing emission control. Since door leakage is so variable, the representativeness of the limited available data is uncertain.

PUSHING

After the volatile matter has been driven off and the coal has been coked, the oven is ready to be pushed. A push ram operated from the push machine aligns with the push side door of the oven. On the coke side of the oven, a quench car and coke guide move into position. The doors at both ends of the oven are removed and the ram is inserted into the oven. The coke is pushed out of the oven, through the coke guide, and into the quench car. The quench car is then transported along the battery tracks to the quench tower for cooling of coke by water sprays. The pushing of coke usually takes 1 to 3 minutes to complete.

Uncontrolled pushing emissions consist of particulates and gaseous, organic matter. Particulate emissions consist of fine coke particles produced by abrasion of the larger coke pieces during movement from the oven and the fall into the quench car. A thermal plume from the hot coke mass entrains the coke particles (often termed "coke breeze") into a visible plume of high opacity above the battery, if not controlled. Some of the coke breeze particles are of a large enough size to settle to the ground near the battery.

Gaseous emissions during the push originate from two sources. Since coke is porous, some coke oven gas contained in the coke mass contacts the atmosphere and ignites during the push. This gas, present at the end of the coking cycle, has been characterized as containing 335 Btu/ft^5, and a percent by volume composition as follows: H_2 - 83.3; CO - 5.3; CH_4 - 5.6; N_2 - 5.5 ; CO_2 and H_2S - 0.3.[5,6] The sulfur content of coke is usually low, typically about 0.005 lb/ton coke.[5] Plant operators strive for low-sulfur coke since sulfur is an impurity in iron which requires removal prior to steelmaking.

Gaseous emissions during the push may also evolve from portions of the coke mass which still contain some volatile matter. Plant operators refer to incompletely coked coal as "green" coke or "green" pushes. Green coke arises from several causes including: (a) uneven flue heating, causing cold spots on oven walls; (b) damaged door refractory which allows excessive cooling at oven ends; (c) too short a coking cycle due to operator (scheduling) error or rapid production rates. When uncoked (green) portions of the coke mass contact ambient air, they usually ignite, generating flames and combustion products.

Almost all currently-operating batteries have installed equipment to capture and clean pushing emissions. Three basic types of technology have been applied in the United States, i.e.: (a) mobile scrubber cars; (b) traveling hoods with fixed exhaust ducts and land-based, conventional gas cleaners; and (c) sheds with land-based gas cleaners.

Mobile scrubber cars comprise about 40 percent of the pushing cleaning systems installed to date. This system includes a hood enclosing the coke guide, coupled to a specially-designed quench car. One or more exhaust ducts attached to the enclosed guide and quench car evacuate pushing emissions into a gas cleaning car attached to the quench car. Conventional scrubbing equipment mounted within the gas cleaning car cleans the exhaust stream, discharging through mist eliminators and a short stack. The gas cleaning car contains scrubbing water pumps, steam ejector nozzles or conventional fans for gas movement, and auxilliary scrubbing equipment. Prominent examples of this technology include the Envirotech/Chemico Halcon-II and Halcon-III Systems; the Koppers car (in several configurations); and the Granite City car.

About 40 percent of currently-operable batteries use traveling hood/fixed duct systems. Here, a hood enclosing the coke guide and quench car is connected to a stationary exhaust duct running along the entire length of the battery. The hood is exhausted via fans to a conventional gas cleaner located at the end of the battery. Several different designs are offered by equipment vendors. The Minister-Stein system uses a flexible belt arrangement which continuously connects the exhaust hood to the exhaust duct. This provides the option to control quench car emissions during travel to the quench tower. The Mitsubishi and the McKee-Otto designs use telescoping ducts to connect the hood into hatches along the fixed exhaust duct. This arrangement cannot control quench car emissions during travel to the quench car.

The coke-side shed, used for about 20 percent of currently operable batteries, consists of a large enclosure covering the quench car tracks. The shed extends along the entire length of the battery, often up to the quench tower, for capture of pushing and travel emissions. The shed is exhausted through its top to a conventional gas cleaner located at one end of the shed. The shed is also capable of capturing emissions from door leaks.

QUENCHING

Immediately after the push, the coke is cooled in a quench tower to restrict coke loss from combustion. The quench tower is located at one end of the battery (or group of batteries). Quench towers are constructed of brick, cement, or corrugated steel sheeting. The quench car enters an opening at the tower base where approximately 270 gallons of water per ton of coke[9] is applied through spray nozzles over a 1 or 2-minute period. Quenching typically reduces coke temperature from about 2,000°F to 180°F.[8] After quenching, the coke is discharged to an inclined platform located along the coke side of the battery, termed the wharf. From the wharf, coke is transferred by gravity gates into the screening station. A schematic of a typical quench tower system appears in Figure 6.

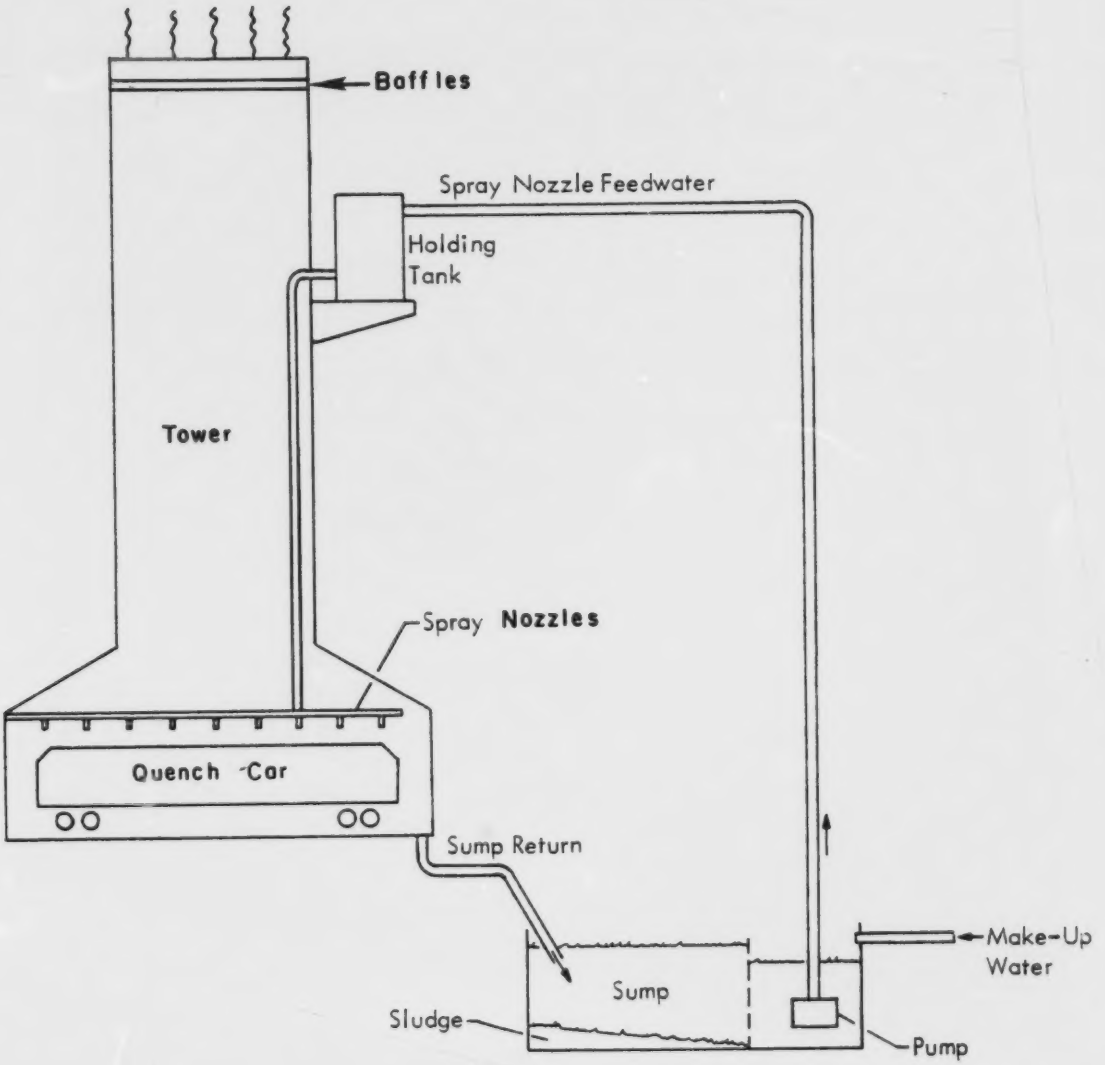


Figure 6. Schematic diagram of a wet quench tower.[10]

Quench tower emissions consist of steam and entrained particulate (coke breeze) and trace organic emissions. About 180 gallons of water per ton of coke[9] evaporates and forms a highly-visible steam plume exiting the tower top via natural draft.

Quench towers are controlled in the industry by different arrangements of baffles located near the tower top which remove particulate by impingement on baffle surfaces. Conventional baffles consist of a single row of wood 2 x 10s, spaced about 1 foot apart at an angle between 20° and 45° from vertical. More efficient baffles include: (a) double rows of conventional wood baffles; (b) special tower designs with offset tops to improve particulate retention; and (c) plastic "chevron" type baffles similar to mist eliminators in wet scrubber systems. These more efficient baffles often have water flushing systems to prevent particle buildup and baffle clogging.

Field measurements have found a correlation between particulate emissions and the total dissolved solids (TDS) content of the quench water. Historically, the quench water was heavily-contaminated wastewater, usually from the byproduct plant. So-called "dirty" quench water with TDS greater than 5,000 ppm has been shown to substantially increase quench tower emissions. So-called "clean" water with TDS less than 1,500 ppm has been shown to minimize emissions.[10] Approximately one-half of domestic coke plants currently use so-called clean water. Most plants use baffles, but the configuration and degree of maintenance is highly variable between plants.

All domestic coke plants use wet quench towers. Some foreign plants use a different system based on heat recovery using inert gases for cooling of coke. There are no known plans for installation of this technology in the United States.

COKE HANDLING

After the coke is quenched, it is transported in the quench car and dumped on the wharf, usually through doors along the side of the quench car, and the excess water is allowed to drain. Gates on the wharf then open to allow the coke to fall onto a conveyer belt which carries the coke to the crushing and screening stations. Here, the coke is separated to its desired size range(s). The coke fines (breeze) are collected and used in other plant operations or sold.

The emissions generated through coke handling operations are similar to those generated during coal handling. A flow diagram showing a generalized coke-handling system is presented in Figure 7.

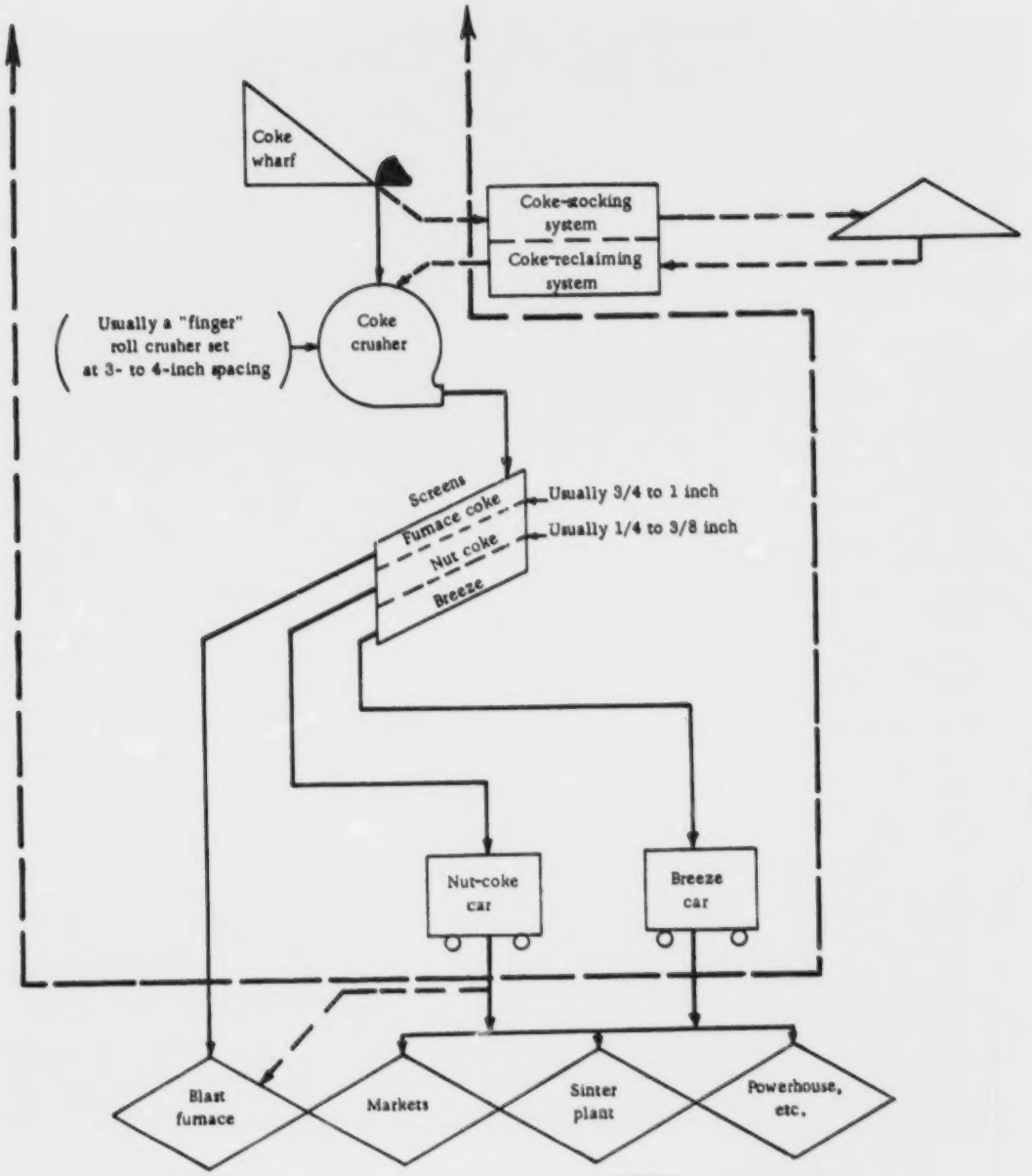


Figure 7. Generalized coke handling system.[1]

REFERENCES

1. Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke, Battelle, January 1970, EPA Report APTD 1250 (NTIS PB 189 266).

2. The Making and Shaping of Steel - 8th Edition, Published by U.S. Steel Co.

3. Coke Oven Emissions from By-Product Coke Oven Charging, Door Leaks, and Topside Leaks on Wet-Coal Charged Batteries--Background Information for Proposed Standards, U.S. EPA, OAQPS, March 1981, Draft Report.

4. P. Gorman, C. Mumma and J. Shum, Study of Coke Oven Battery Stack Emission Control Technology Final Report - Volume I - Collection and Analyses of Existing Emission Data, Midwest Research Institute, EPA Contract No. 68-02-2609, Task No. 5, U.S. EPA, OAQPS, March 1979, Draft Report.

5. A. Conners and J. Mullen, Developments in Coke-Oven Emission Control, Iron and Steel Engineering, June 1980, Issue 57, pp. 33-38.

6. H. H. Lowry, Chemistry of Coal Utilization, Vol. II, N.Y. 1945.

7. D. A. Masson, Selection and Design of a Coke Side Pushing Emission Control System for Retrofit to Existing Coke Oven Batteries, from Proceedings Control of Air Emissions from Coke Plants, April 1979.

8. G. L. Ertel, Quench Tower Particulate Emissions, from Proceedings Control of Air Emissions from Coke Plants, April 1979.

9. D. Wagner and A. E. Williams, How to Reduce Emissions from Quenching Hot Coke with Water, Ironmaking Conference, 39th, 1980.

10. Coke-Wet Quenching - Background Information for Proposed Standards, U.S. EPA, OAQPS, March 1982, Draft Report.

11. World Steel Industry Data Handbook, Volume 5, USA, 1982.

SECTION 3

METALLURGICAL COKE EMISSION FACTORS

TOTAL AND SIZE-SPECIFIC EMISSION FACTORS

Emission factors for total particulate have been updated for the metallurgical coke industry using data from the test reports used to calculate the current AP-42 Metallurgical Coke Section (10/80), in addition to other, more recent reports. Size specific emission factors have also been calculated based on cascade impactor test results. These total and size specific emission factors are listed in Tables 1 and 2 respectively. The data used to develop these emission factors are summarized in Tables 3 to 24 for total particulate measurements, and Figures 8 to 18 for particle size measurements.

The quantity and quality of emission factor data for coke plants have increased substantially over the past few years. However, much of the data is not fully supported by a complete test report and plant process and production data. Available data include total particulate, as well as particle sizing data, on controlled and uncontrolled emissions. The procedures used in compiling this information, calculating the emissions factors and rating the emission factors are detailed in the following pages.

DATA REVIEW PROCEDURES

All available sources of data were reviewed for the compilation of emissions factors. There were limited particle size data available from EPA's Fine Particle Emission Information System (FPEIS). Reference sources which reported the results of actual measurements and observations were considered primary data sources. Reference sources which referred to emission data developed and reported by a different organization or author were considered secondary sources.

Only primary sources were considered suitable for calculating emission factors when several primary sources were available. If limited or no primary source data were available, then secondary sources were considered. In the data review process each source of emission data was judged to determine if it should be considered a primary or secondary source. If the data were judged secondary, an attempt was made to obtain the primary sources on which it was based.

TABLE 1. EMISSION FACTORS FOR COKE MANUFACTURING[a]

Type of operation	Particulate emission factor rating[b]	Particulates[b]		Sulfur dioxide[c]		Carbon monoxide[c]		Volatile organic[c,d]		Nitrogen oxides[c]		Ammonia[c]	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Coal crushing with cyclone	D	0.055	0.11	-	-	-	-	-	-	-	-	-	-
Coal preheating													
Uncontrolled[e]	C	1.75	3.50	-	-	-	-	-	-	-	-	-	-
With scrubber	C	0.125	0.25	-	-	-	-	-	-	-	-	-	-
With wet ESP	C	0.006	0.012	-	-	-	-	-	-	-	-	-	-
Wet coal charging[f]													
Larry car (uncontrolled)	E	0.24	0.48	0.01	0.02	0.3	0.6	1.25	2.5	0.015	0.03	0.01	0.02
Larry car with sequential charging	E	0.008	0.016	-	-	-	-	-	-	-	-	-	-
Larry car with scrubber	E	0.007	0.014	-	-	-	-	-	-	-	-	-	-
Door leaks (uncontrolled)	D	0.27	0.54	-	-	0.3	0.6	0.75	1.5	0.005	0.01	0.03	0.06
Coke pushing													
Uncontrolled	B	0.58	1.15	-	-	0.035	0.07	0.1	0.2	-	-	0.05	0.01
With ESP[g]	C	0.225	0.45	-	-	-	-	-	-	-	-	-	-
With Venturi scrubber[h]	D	0.09	0.18	-	-	-	-	-	-	-	-	-	-
With baghouse[h]	D	0.045	0.09	-	-	-	-	-	-	-	-	-	-
With mobile Scrubber car[i]	C	0.036	0.072	-	-	-	-	-	-	-	-	-	-
Quenching													
Uncontrolled (dirty water)[j]	D	2.62	5.24	-	-	-	-	-	-	-	-	-	-
Uncontrolled (clean water)[k]	D	0.57	1.13	-	-	-	-	-	-	-	-	-	-
With baffles (dirty water)[j]	B	0.65	1.30	-	-	-	-	-	-	-	-	-	-
With baffles (clean water)[k]	B	0.27	0.54	-	-	-	-	-	-	-	-	-	-

(continued)

TABLE 1 (continued)

Type of operation	Particulate emission factor rating[b]	Particulates[b]		Sulfur dioxide[c]		Carbon monoxide[c]		Volatile organic[c,d]		Nitrogen oxides[c]		Ammonia[c]	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Combustion stacks													
Uncontrolled (COG)	A	0.234	0.47	2.0[l]	4.0	-	-	-	-	-	-	-	-
Uncontrolled (BFG)	A	0.085	0.17	-	-	-	-	-	-	-	-	-	-
With ESP (COG)	B	0.046	0.091	-	-	-	-	-	-	-	-	-	-
With baghouse (COG)	B	0.055	0.11	-	-	-	-	-	-	-	-	-	-
Coke handling[m]													
With cyclone	D	0.003	0.006	-	-	-	-	-	-	-	-	-	-

[a]Emission factors expressed as units per weight of coal charged. Dash: no available data.

[b]References cited in Tables 3 to 24.

[c]References 82 and 83.

[d]Expressed as methane.

[e]Exhaust gas discharged from the series of primary and secondary cyclones that are used to separate the flash-dired coal from the hot gas.

[f]Charged coal has not been dried.

[g]Emissions captured by coke side shed.

[h]Emissions captured by traveling hood.

[i]Emissions captured by quench car enclosure.

[j]Dirty water >5,000 mg/L Total Dissolved Solids.

[k]Clean water <1,500 mg/L Total Dissolved Solids.

[l]Reference 84. The sulfur dioxide factor is based on the following representative conditions: (1) sulfur content of coal charged to oven is 0.8 weight percent; (2) about 33 weight percent of total sulfur of the coal charged to oven is transferred to the coke oven gas; (3) about 40 percent of the coke oven gas is burned during the underfiring operation, the remainder is used in other parts of the steel operation where the rest of the SO_2 is discharged - about 6 lb/ton (3 kg/MT) of coal charged; and (4) the gas used in underfiring has not been desulfurized.

[m]Handling defined as crushing and screening.

TABLE 2. SIZE SPECIFIC EMISSION FACTORS FOR COKE MANUFACTURING

Process	Particulate emission factor rating	Particle size (μm)	Cumulative mass % ≤ stated size	Cumulative mass emission factors kg/Mg	Cumulative mass emission factors lb/ton	Reference source number
Coal preheating Uncontrolled	D	0.5	44	0.8	1.5	5
		1.0	48.5	0.8	1.7	
		2.0	55	1.0	1.9	
		2.5	59.5	1.0	2.1	
		5.0	79.5	1.4	2.8	
		10.0	97.5	1.7	3.4	
		15.0	99.9	1.7	3.5	
			100	1.7	3.5	
Controlled with venturi scrubber	D	0.5	78	0.10	0.20	5
		1.0	80	0.10	0.20	
		2.0	83	0.10	0.21	
		2.5	84	0.11	0.21	
		5.0	88	0.11	0.22	
		10.0	94	0.12	0.24	
		15.0	96.5	0.12	0.24	
			100	0.12	0.25	
Coal charging Sequential or stage	E	0.5	13.5	0.001	0.002	11
		1.0	25.2	0.002	0.004	
		2.0	33.6	0.003	0.005	
		2.5	39.1	0.003	0.006	
		5.0	45.8	0.004	0.007	
		10.0	48.9	0.004	0.008	
		15.0	49.0	0.004	0.008	
			100	0.008	0.016	
Coke pushing Uncontrolled	D	0.5	3.1	0.02	0.04	44,47,50, 51,80,81
		1.0	7.7	0.04	0.09	
		2.0	14.8	0.09	0.17	
		2.5	16.7	0.10	0.19	
		5.0	26.6	0.15	0.30	
		10.0	43.3	0.25	0.50	
		15.0	50.0	0.29	0.58	
			100	0.58	1.15	

(continued)

TABLE 2 (continued)

Process	Particulate emission factor rating	Particle size (μm)	Cumulative mass % ≤ stated size	Cumulative mass emission factors kg/Mg	Cumulative mass emission factors lb/ton	Reference source number
Controlled with Venturi scrubber	D	0.5	24	0.02	0.04	80, 81
		1.0	47	0.04	0.08	
		2.0	66.5	0.06	0.12	
		2.5	73.5	0.07	0.13	
		5.0	75	0.07	0.13	
		10.0	87	0.08	0.16	
		15.0	92	0.08	0.17	
			100	0.09	0.18	
Mobile scrubber car	D	1.0	28.0	0.010	0.020	62
		2.0	29.5	0.011	0.021	
		2.5	30.0	0.011	0.022	
		5.0	30.0	0.011	0.022	
		10.0	32.0	0.012	0.024	
		15.0	35.0	0.013	0.023	
			100	0.036	0.072	
Quenching Uncontrolled (dirty water)	D	1.0	13.8	0.36	0.72	76
		2.5	19.3	0.51	1.01	
		5.0	21.4	0.56	1.12	
		10.0	22.8	0.60	1.19	
		15.0	26.4	0.69	1.38	
			100	2.62	5.24	
Uncontrolled (clean water)	D	1.0	4.0	0.02	0.05	76
		2.5	11.1	0.06	0.13	
		5.0	19.1	0.11	0.22	
		10.0	30.1	0.17	0.34	
		15.0	37.4	0.21	0.42	
			100	0.57	1.13	
With baffles (dirty water)	D	1.0	8.5	0.06	0.11	76
		2.5	20.4	0.13	0.27	
		5.0	24.8	0.16	0.32	
		10.0	32.3	0.21	0.42	
		15.0	49.8	0.32	0.65	
			100	0.65	1.30	

(continued)

TABLE 2 (continued)

Process	Particulate emission factor rating	Particle size (μm)	Cumulative mass % ≤ stated size	Cumulative mass emission factors		Reference source number
				kg/Mg	lb/ton	
With baffles (clean water)	D	1.0	1.2	0.003	0.006	76
		2.5	6.0	0.02	0.03	
		5.0	7.0	0.02	0.04	
		10.0	9.8	0.03	0.05	
		15.0	15.1	0.04	0.08	
			100	0.27	0.54	
Combustion stack Uncontrolled	D	1.0	77.4	0.18	0.36	17,78,79
		2.0	85.7	0.20	0.40	
		2.5	93.5	0.22	0.44	
		5.0	95.8	0.22	0.45	
		10.0	95.9	0.22	0.45	
		15.0	96	0.22	0.45	
			100	0.23	0.47	

TABLE 3. SOURCE EMISSION FACTORS: COAL CRUSHING--WITH CYCLONE

Reference No.	Rating	lb/ton coal	Comments
1	B	0.11	1 run, cyclone collector on coal crushing
Average:	D	0.11	

TABLE 4. SOURCE EMISSION FACTORS: PREHEATERS--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
4	B	0.32	Average of 12 runs
5	A	7.04	Average of 18 (used in 1980 AP-42 update)
6	A	3.13	Average of 3 runs
Average:	C	3.50	

TABLE 5. SOURCE EMISSION FACTORS: PREHEATER--WITH SCRUBBER

Reference No.	Rating	lb/ton coal	Comments
2	B	0.20	Average of 3 runs
3	B	0.14	Average of 3 runs
4	B	0.012	Average of 12 runs
5	A	0.65	Average of 18 runs (used in 1980 AP-42 update)
6	A	0.26	Average of 3 runs
8a	C	0.37	1 run (not used in emission factors)
8b	C	0.22	1 run (not used in emission factors)
Average:	C	0.25	

TABLE 6. SOURCE EMISSION FACTORS: PREHEATERS--WITH WET ESPs

Reference No.	Rating	lb/ton coal	Comments
7	B	0.013	Average of 3 runs
9a	A	0.0043	Average of 3 runs
9b	A	0.021	Average of 3 runs
9c	A	0.0081	Average of 3 runs
Average:	C	0.012	

TABLE 7. SOURCE EMISSION FACTORS: CHARGING--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
11a	C	0.108	Wilputte Car (used in 1980 AP-42 update)
13	C	0.85	Used in 1980 AP-42
Average:	E	0.48	

TABLE 8. SOURCE EMISSION FACTORS: CHARGING--SEQUENTIAL

Reference No.	Rating	lb/ton coal	Comments
11b	C	0.016	EPA/AISI Car (used in 1980 AP-42 update)
Average:	E	0.016	

TABLE 9. SOURCE EMISSION FACTORS: CHARGING--SCRUBBER ON LARRY CARS

Reference No.	Rating	lb/ton coal	Comments
10a	C	0.021	Scrubber pilot burners on, normal operation (used in 1980 AP-42 update)
10b	C	0.026	Normal charge - burners off (not used in emission factor)
10c	C	0.101	Delayed charge - burners on (not used in emission factor)
12a	D	0.012	Average of 2 runs with low energy Krupp scrubber
12b	D	0.008	Low energy centrifugal dust collector with mist eliminators, method VDI 2302
Average:	E	0.014	

TABLE 10. SOURCE EMISSION FACTORS: COG UNDERFIRING--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
18	A	0.098	Average of 4 runs
19	A	0.098	Average of 3 runs
20	A	0.73	Average of 3 runs
21	A	1.24	Average of 3 runs
22	A	0.47	Average of 3 runs
23	A	0.86	Average of 3 runs
24	A	0.79	Average of 3 runs
25	A	0.74	Average of 3 runs
26	A	0.29	Average of 3 runs
27	A	0.44	Average of 3 runs
28	A	0.53	Average of 3 runs
29	A	0.48	Average of 3 runs
30	A	0.51	Average of 3 runs
31	A	0.12	Average of 3 runs
32	A	0.33	Average of 3 runs
33	A	0.15	Average of 3 runs
34	A	0.11	Average of 3 runs
37	A	0.21	Average of 4 runs
Average:	A	0.47	

TABLE 11. SOURCE EMISSION FACTORS: BFG UNDERFIRING--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
14	A	0.27	Average of 19 runs
18	A	0.040	Average of 3 runs
23	A	0.25	Average of 3 runs
24	A	0.13	Average of 3 runs
Average:	A	0.17	

TABLE 12. SOURCE EMISSION FACTORS: COG UNDERFIRING--WITH ESP

Reference No.	Rating	lb/ton coal	Comments
15	A	0.091	Average of 3 runs
16	C	0.26	Average of 5 runs (not used in emission factor)
35	C	0.032	Average of 4 runs (not used in emission factor)
36	C	0.048	Average of 3 runs (not used in emission factor)
Average:	D	0.091	

TABLE 13. SOURCE EMISSION FACTORS: COG UNDERFIRING--WITH BAGHOUSE

Reference No.	Rating	lb/ton coal	Comments
38a	B	0.19	Average of 2 runs
38b	B	0.051	Average of 3 runs, silicon-graphite treated bags
38c	B	0.074	Average of 3 runs, silicon-graphite treated bags
Average:	D	0.11	

TABLE 14. SOURCE EMISSION FACTORS: PUSHING--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
39a	A	2.31	Average of 3 runs (shed)
41	B	4.38	Average of 3 runs (shed) - not used in final emission factor
44	A	0.41	Average of 11 runs (shed)
47	A	0.46	Average of 4 runs (shed)
51	A	0.69	Average of 3 runs (shed)
50	A	1.90	Average of 7 runs (travelling hood)
Average:	B	1.15	

TABLE 15. SOURCE EMISSION FACTORS: PUSHING--WITH WET ESP

Reference No.	Rating	lb/ton coal	Comments
39a	A	0.19	Average of 3 runs (shed)
39b	B	1.11	Average of 4 runs (shed)
40	B	0.11	Average of 2 runs (shed)
42	B	0.31	Average of 4 runs (shed)
49	B	0.55	Average of 6 runs (shed)
Average:	C	0.45	

TABLE 16. SOURCE EMISSION FACTORS: PUSHING--WITH VENTURI SCRUBBER

Reference No.	Rating	lb/ton coal	Comments
43	B	0.21	1 run (travelling hood)
45	A	0.13	Average of 3 runs (travelling hood)
46	B	0.37	Average of 3 runs (travelling hood)
48	C	0.072	Average of 3 runs (not used in emission factor)
50	A	0.011	Averge of 7 runs (travelling hood)
Average:	D	0.18	

TABLE 17. SOURCE EMISSION FACTORS: PUSHING--WITH BAGHOUSE

Reference No.	Rating	lb/ton coal	Comments
52	A	0.19	Average of 3 runs (travelling hood)
53	A	0.004	Average of 3 runs (travelling hood)
54	A	0.079	Average of 3 runs (travelling hood)
Average:	D	0.091	

TABLE 18. SOURCE EMISSON FACTORS: PUSHING--WITH MOBILE SCRUBBER CAR

Reference No.	Rating	lb/ton coal	Comments
55a	C	0.022	Average of 3 runs (not used in emission factor)
55b	C	0.017	Average of 3 runs (not used in emission factor)
56a	B	0.026	Average of 3 runs, Chemico H-3 Car
56b	B	0.019	Average of 3 runs, Chemico H-3 Car
56c	B	0.024	Average of 3 runs, Chemico H-3 Car
57	C	0.38	Average of 7 runs (not used in emission factor)
58	B	0.012	Average of 4 runs, Chemico Car
59a	B	0.099	Average of 3 runs, Chemico H-3 Car
59b	B	0.060	Average of 6 runs, Chemico H-3 Car
60	B	0.049	Average of 3 runs, Chemico H-3 Car
61	A	0.037	Average of 3 runs, Chemico H-2 Car
62	A	0.33	Average of 3 runs, Kopper Car
63	B	0.047	Average of 3 runs, Koppers Car
64	A	0.12	Average of 3 runs, U.S. Steel Car
65	B	0.39	Average of 3 runs, Chemico H-2m Car
66	B	0.015	Koppers Car
67	B	0.011	Average of 8 runs, Chemico H-2 Car
68a	B	0.034	Average of 3 runs, Granite City Car
68b	B	0.033	Average of 4 runs, Granite City Car

(continued)

TABLE 18 (continued)

Reference No.	Rating	lb/ton coal	Comments
69	B	0.011	Average of 3 runs, Koppers Car
70	A	0.025	Average of 3 runs, Granite City Car
71	A	0.030	Average of 3 runs
Average:	C	0.072	

TABLE 19. SOURCE EMISSION FACTORS: DOOR LEAKS--UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
13	B	0.51	Taken from EPA-450/4-79-028 (doubled to take into account both sides of battery)
72	A	0.68	Average of 3 runs on coke shed during non-pushing (doubled to account for both sides of battery)
73	A	0.44	Average of 3 runs on coke shed during non-pushing (doubled to account for both sides of battery)
Average:	D	0.54	

TABLE 20. SOURCE EMISSION FACTORS: QUENCHING--CLEAN WATER[a] UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
76	A	1.13	Average of 5 runs
Average:	D	1.13	

[a]<1500 mg/l TDS.

TABLE 21. SOURCE EMISSION FACTORS: QUENCHING--DIRTY WATER[a] UNCONTROLLED

Reference No.	Rating	lb/ton coal	Comments
76	A	5.24	Average of 4 runs
Average:	D	5.24	

[a]>5000 mg/l TDS

TABLE 22. SOURCE EMISSION FACTORS: QUENCHING--CLEAN WATER[a] WITH BAFFLES

Reference No.	Rating	lb/ton coal	Comments
74	A	1.46	Average of 13 runs (1 row baffles at 45°)
75	A	0.33	Average of 9 runs (Carlstill plastic baffles)
75	A	0.32	Average of 9 runs (1 row baffles at 45°)
76	A	0.27	Average of 9 runs (2 row baffles at 20°)
76	A	0.32	Average of 5 runs (Munters plastic baffles)
Average:	B	0.54	

[a]<1500 mg/1 TDS

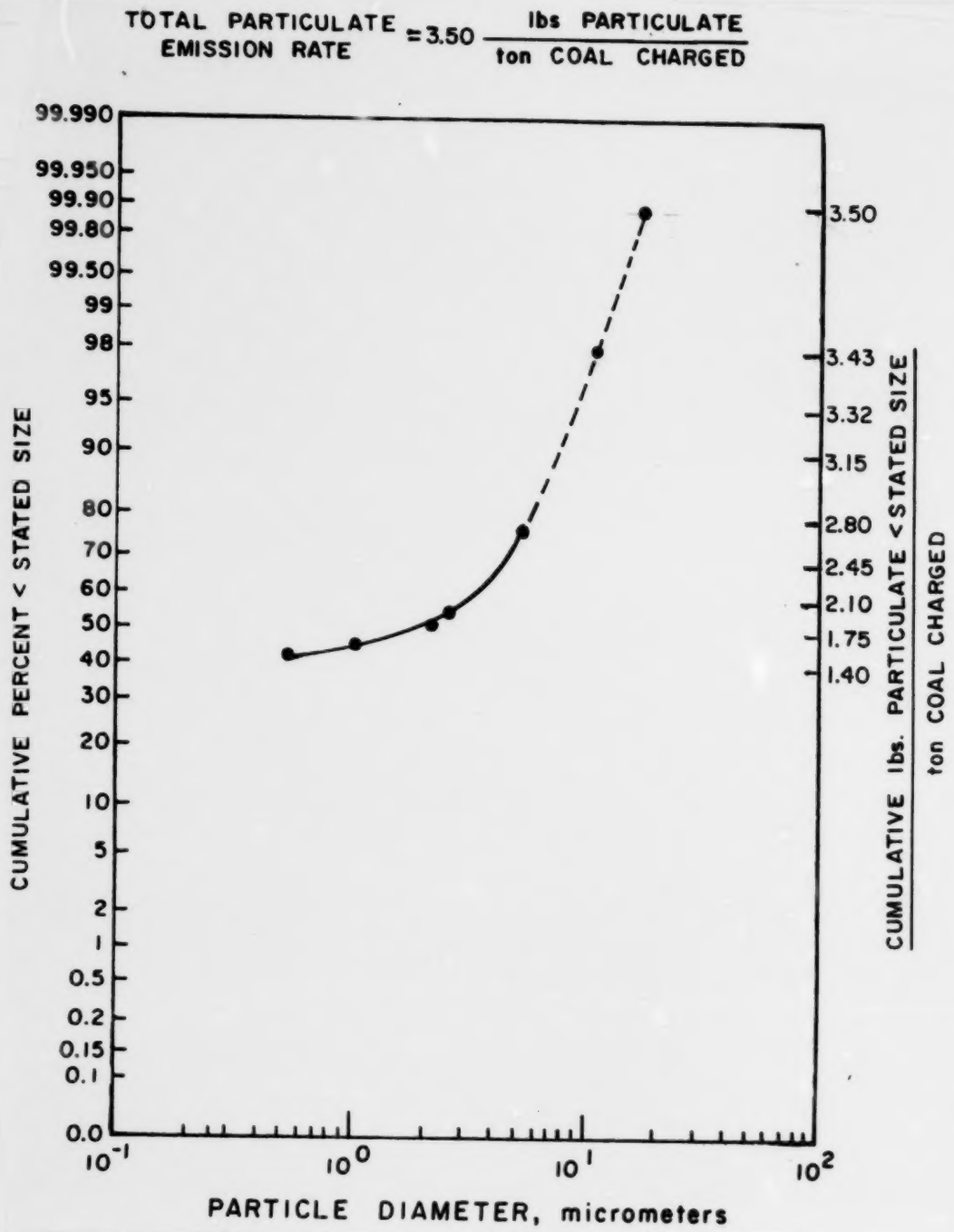
TABLE 23. SOURCE EMISSION FACTORS: QUENCHING--DIRTY WATER[a] WITH BAFFLES

Reference No.	Rating	lb/ton coal	Comments
74	A	2.73	Average of 11 runs (1 row baffles at 45°)
75	A	0.43	Average of 9 runs (Carlstill plastic baffles)
75	A	0.64	Average of 9 runs (1 row baffles at 45°)
76	A	1.39	Average of 4 runs (Munters plastic baffles)
Average:	B	1.30	

[a]>5000 mg/1 TDS

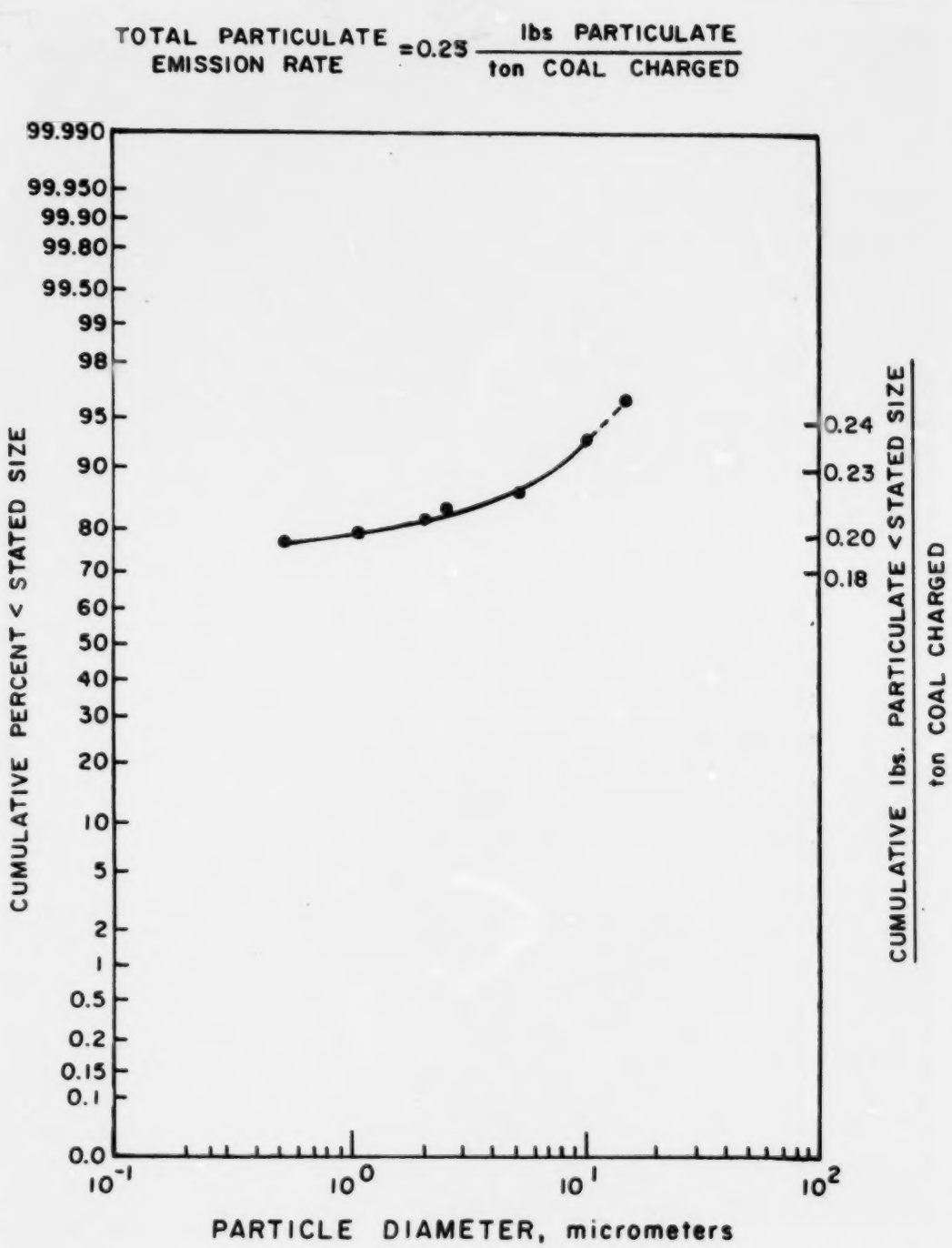
TABLE 24. SOURCE EMISSION FACTORS: COKE HANDLING--WITH CYCLONE

Reference No.	Rating	lb/ton coal	Comments
77	B	0.008	1 run
77	B	0.006	1 run
77	B	0.004	1 run
Average:	D	0.006	



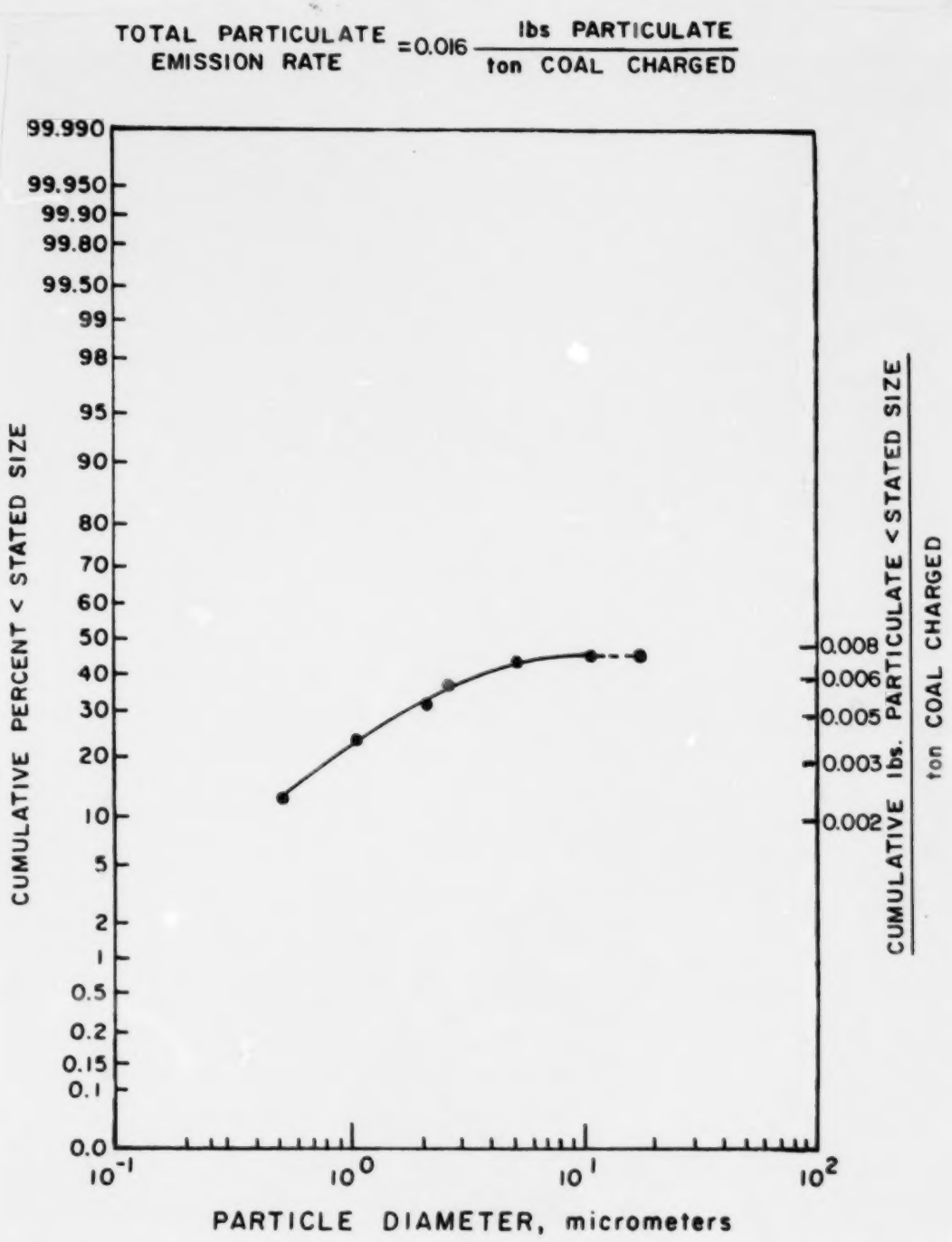
Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 8. Coal preheating (uncontrolled).[5]



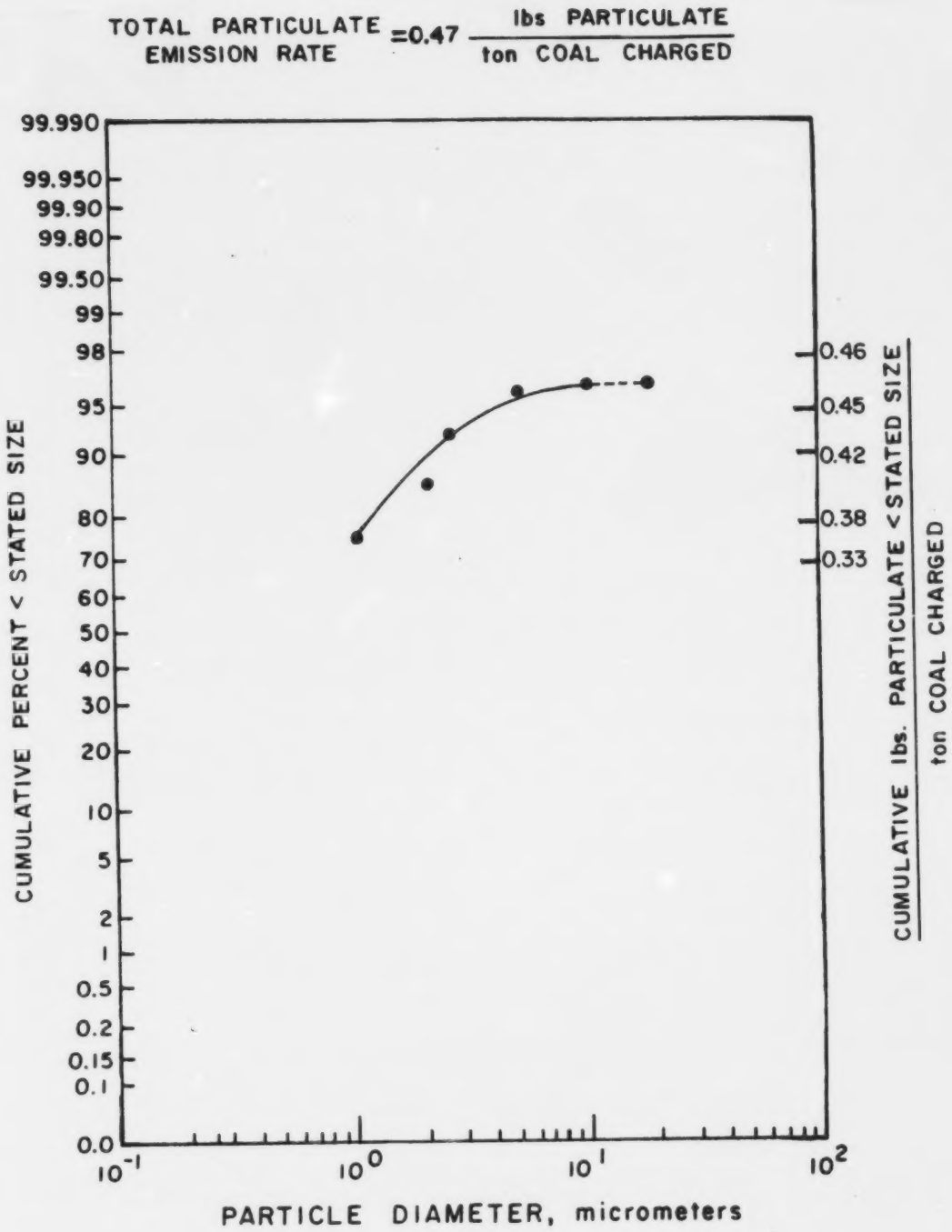
Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 9. Coal preheating (controlled with scrubber).[5]



Note: Extrapolated to the 15 μm size, using engineering estimates.

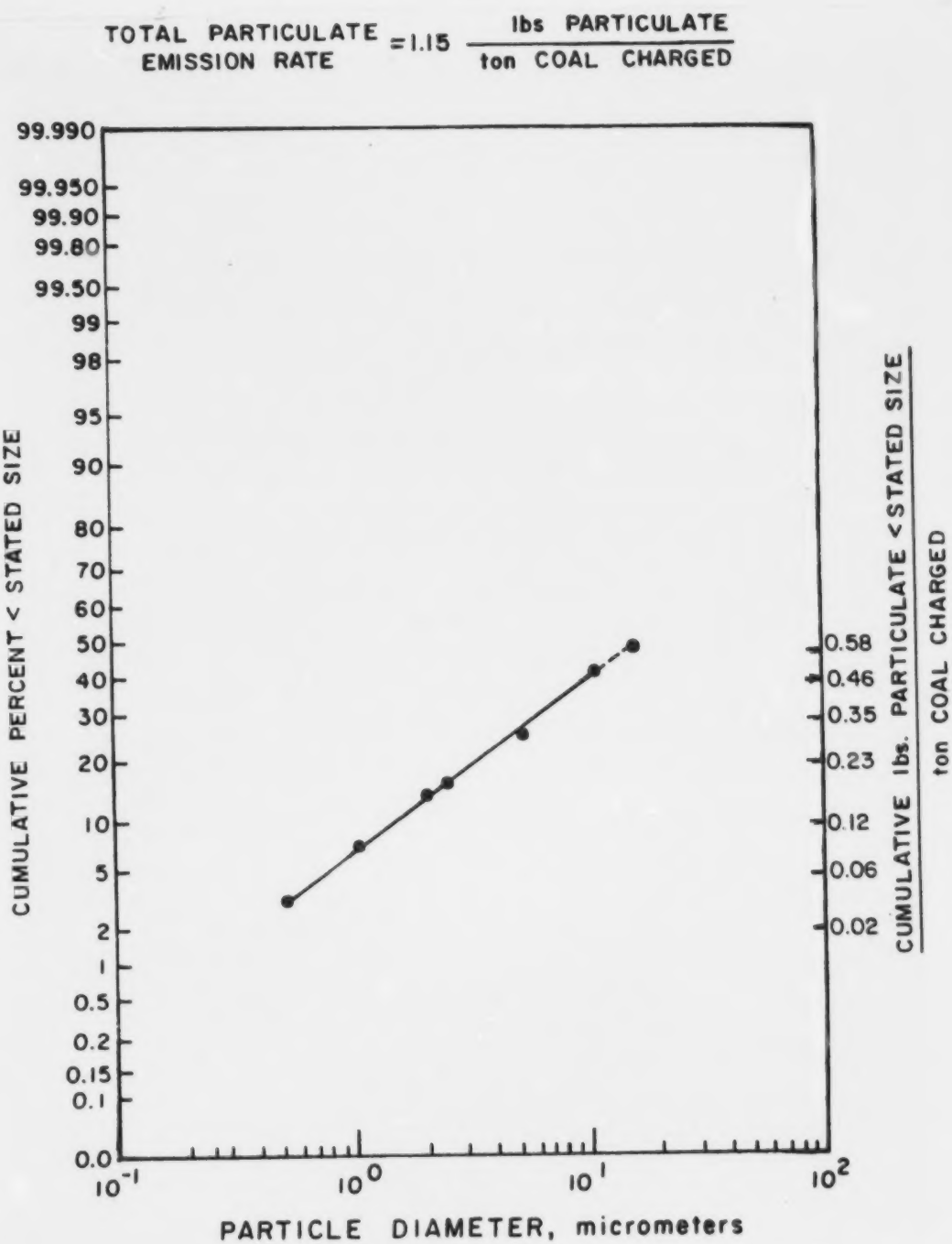
Figure 10. Coal charging (sequential) average of 2 tests.[11]



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 11. Combustion stacks (uncontrolled) average of 3 sites.[17,78,79]

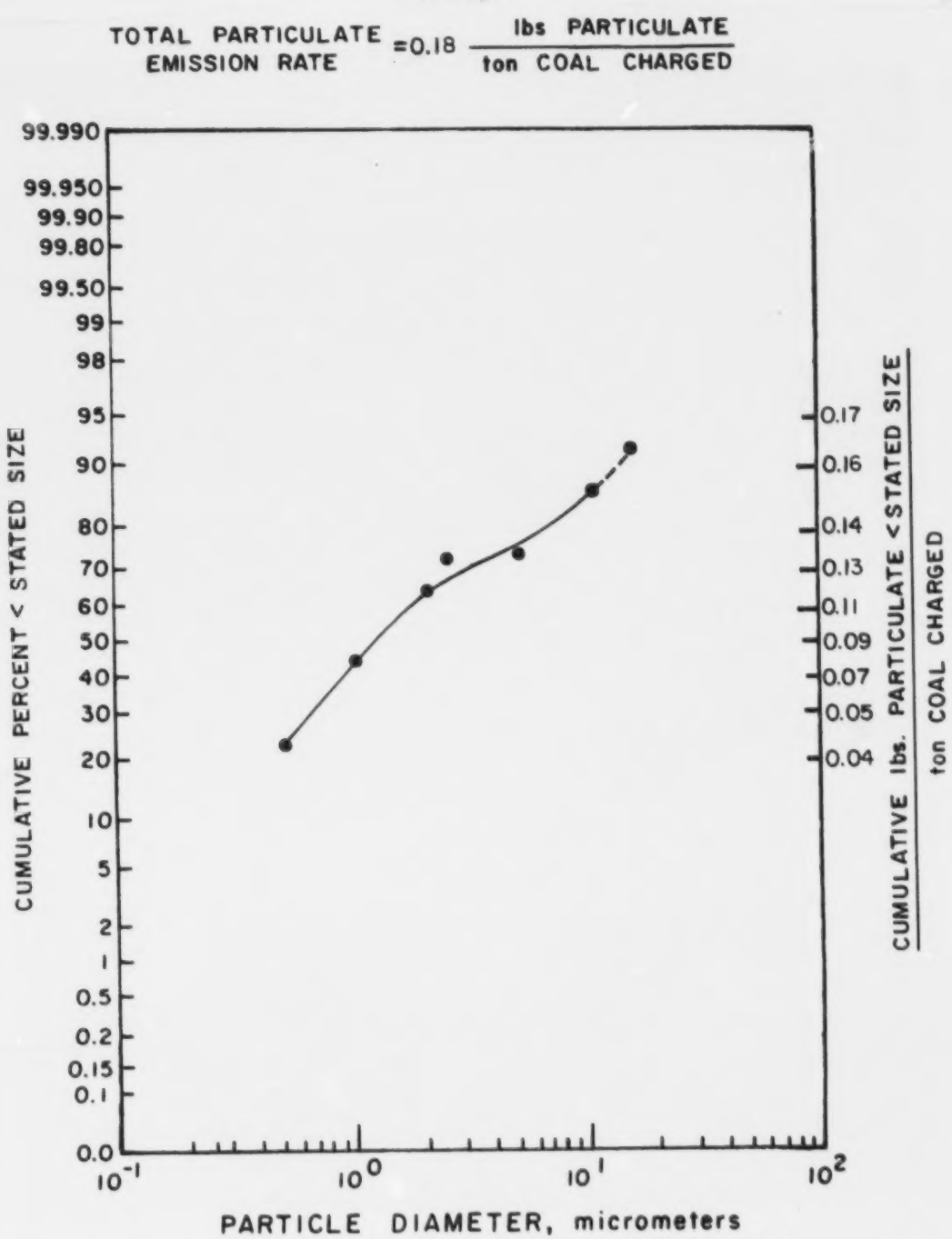
17, 92, 23



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 12. Pushing (uncontrolled) average of 6 sites.[44,47,50,51,80,81]

[44,47,50,51,84,85]



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 13. Pushing (controlled with scrubber) average of 2 sites.[80, 81]

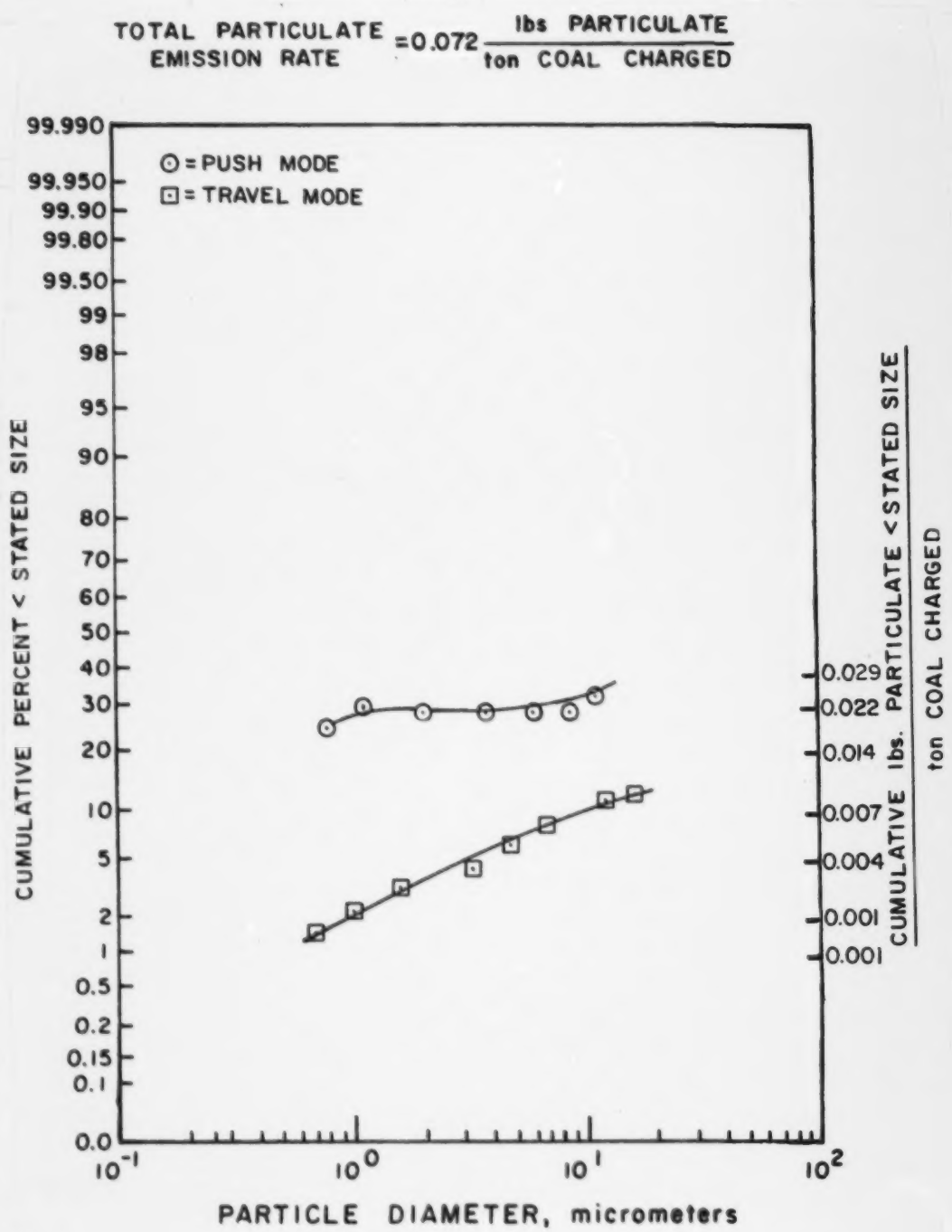


Figure 14. Mobile scrubber cars.[62]

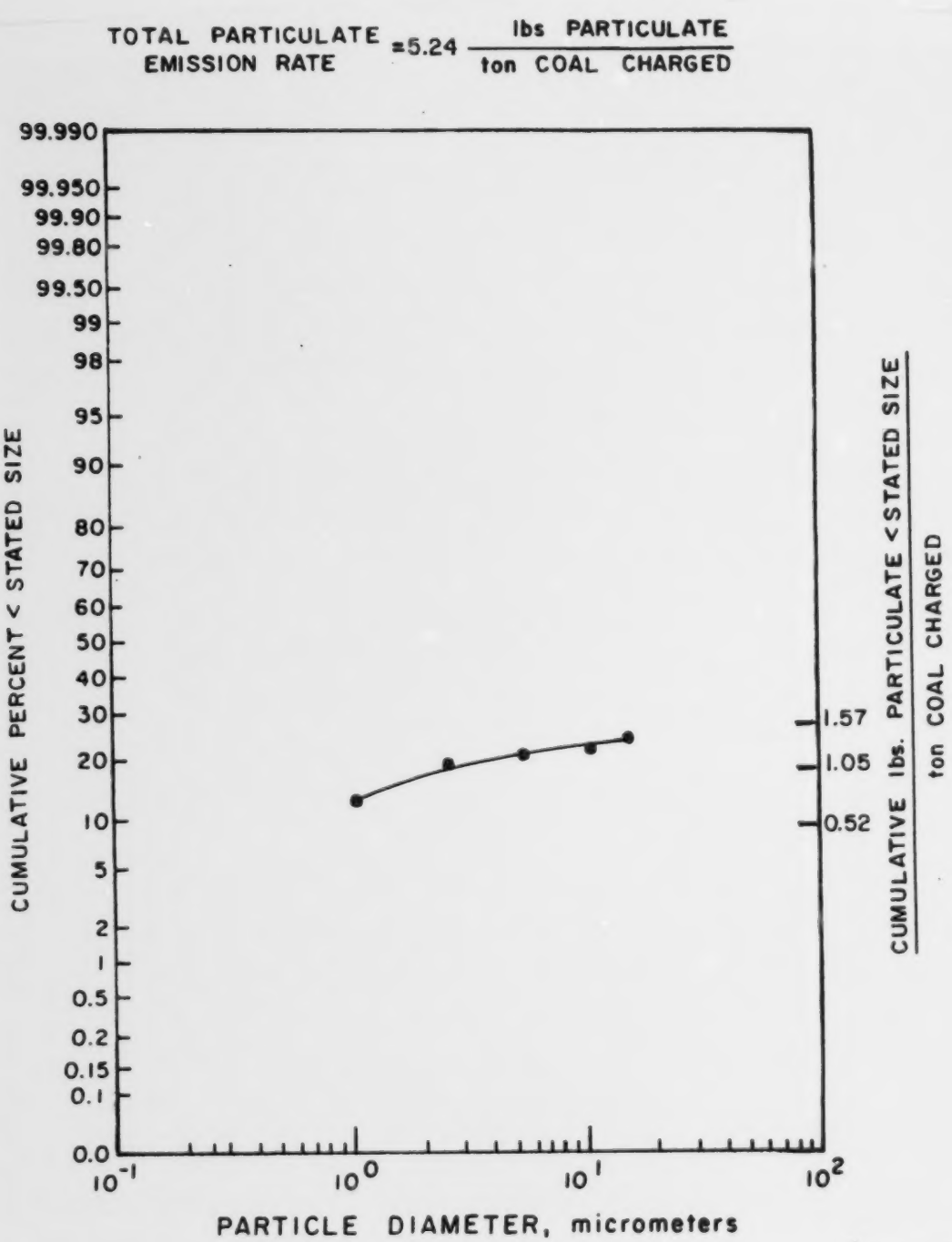


Figure 15. Quenching (uncontrolled) dirty water > 5,000 mg/1 TDS.[76]

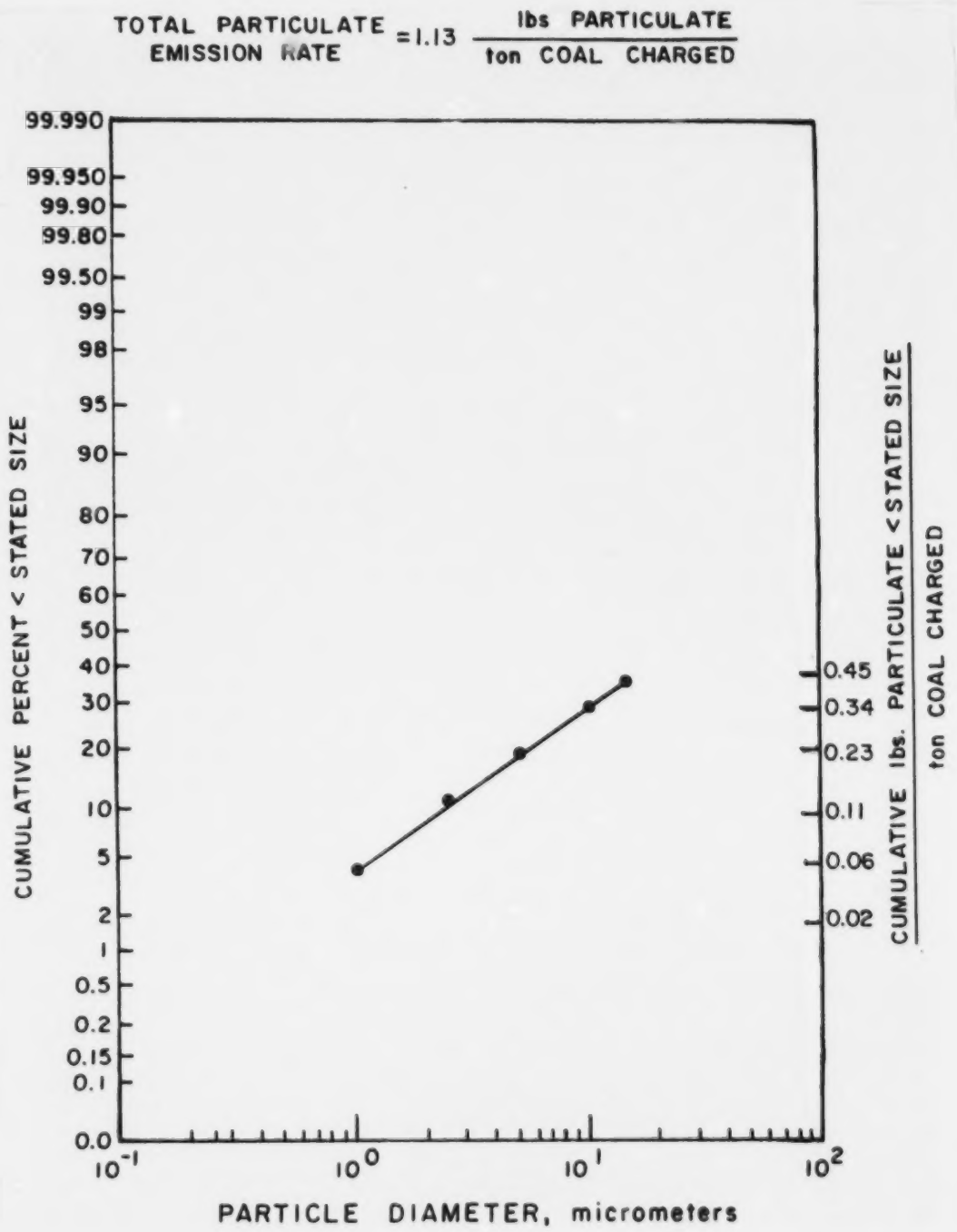


Figure 16. Quenching (uncontrolled) clean water < 1,500 mg/1 TDS.[76]

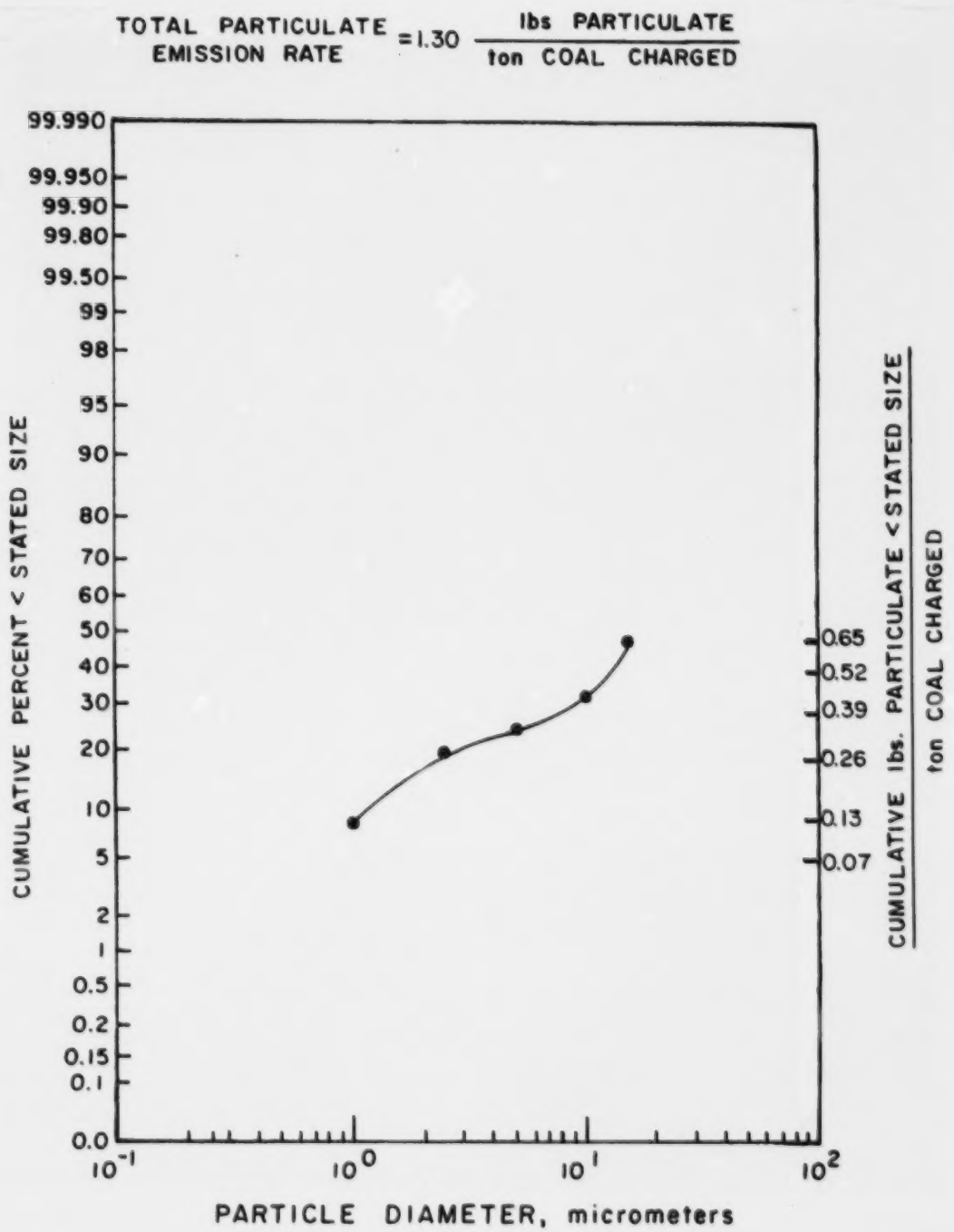


Figure 17. Quenching (controlled--with baffles) dirty water > 5,000 mg/1 TDS.[76]

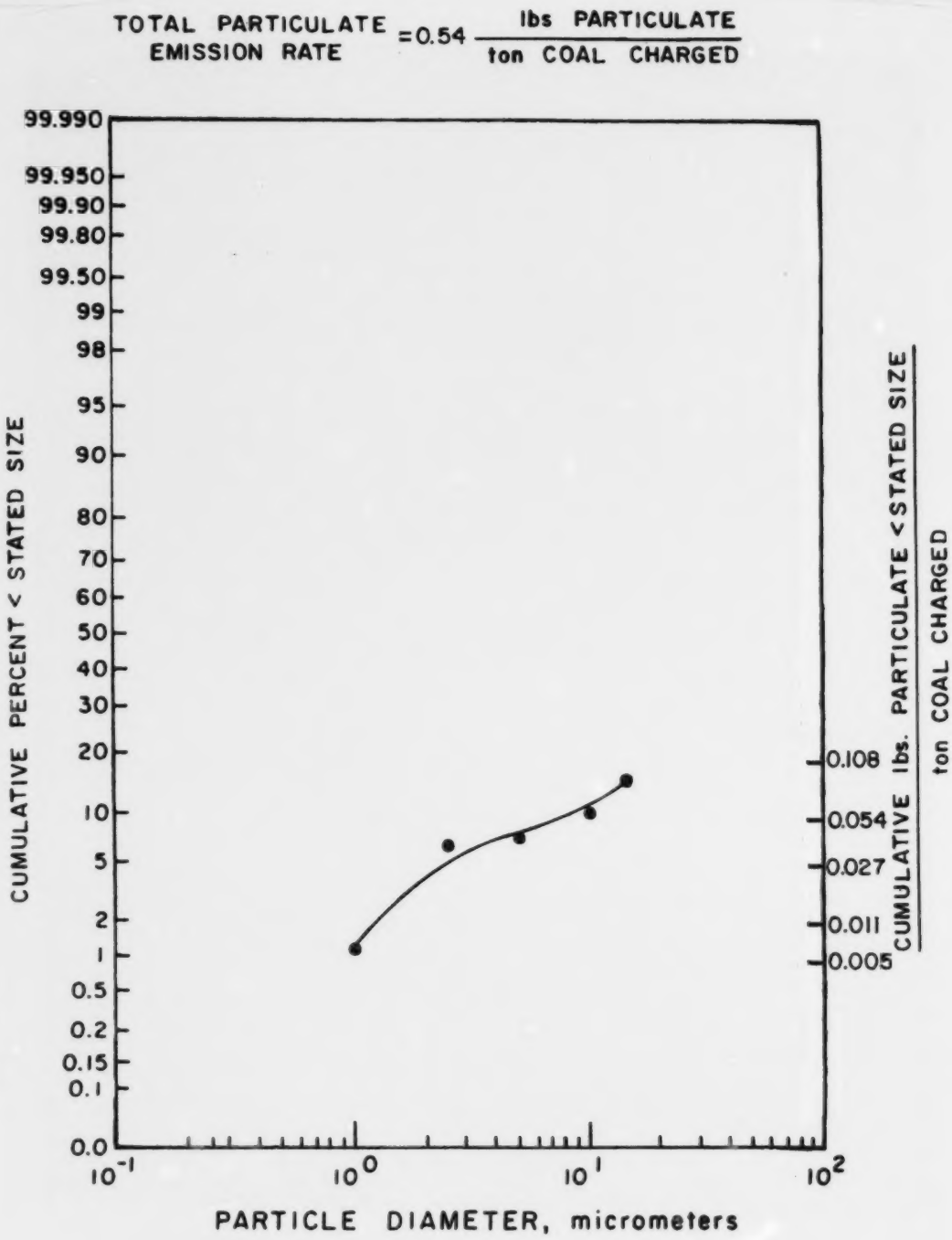


Figure 18. Quenching (controlled - with baffles) clean water < 1,500 mg/1 TDS.[76]

All data sources thus collected were subjected to more extensive review and analysis. The data were ranked using an A through D grading system, based on data quality and reliability according to the criteria described in the manual "Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections," and in Section 1 of this report. The individual sources of data evaluated in this study were rated as follows:

(A) rated data consisted of multiple particulate emission tests conducted in accordance with EPA Reference Method 5 (40 CFR 60 Appendix A). The reports contained enough background and process information to adequately validate the results and to express the emission factors as units per weight of coal charged.

(B) rated data also consisted of particulate testing in accordance with EPA Method 5. These reports contained sufficient background information to validate the results, however, little or no process information was included. In order to express the emission factors as units per weight of coal charged, average production rates for the various coke manufacturing facilities had to be used.

(C) rated data were from reports that contained emission results from an acceptable method without any background or process data to verify the results. These were generally summaries of Emission Test Reports.

(D) rated data were from reports in which the emission results reported were from an unknown or unacceptable method. These were generally old reports with little or no background or process information and were used only to provide an order-of-magnitude value for the source.

The data review process was conducted on numerous data sources. The data contained in each were used to develop an emission factor specific to that source and site. The sources are grouped by metallurgical coke process and emission control device. Source category emission factors were then calculated and rated. The ranking assigned to the emission factors reflects the rankings of the data used to develop that emission factor. Section 1 of this report contains the criteria used to determine the emission factor rating.

A brief summary of all test data reviewed, and the basis for the assigned rank is provided below. All data in the tables are presented in a lb/ton coal charged basis. In some instances, especially with the test reports on pushing, the only available data were reported on a lb/ton coke basis. To maintain uniformity in this report and in the proposed AP-42 Section, all lb/ton coke emissions were converted to lb/ton coal. The conversion factor used for calculating the tonnage of coke produced is 1.0 tons of dry furnace coke for each 1.43 tons of dry coal charged. This is derived from Lowry's Formula using an average volatile matter of 30.1 percent and a yield of 69.93 percent of oven coke. Thus, dividing lb/ton coke by 0.6993 will give an approximate lb/ton coal for a "typical" coke oven battery.

SUMMARY OF TEST DATA

Coal Preparation

The test data for coal preparation were limited to a single Method 5 test of a coal crushing station. This operation is typically the greatest source of particulate emissions during coal preparation, compared to blending and handling operations. The resultant emission factor is rated D (below average) to indicate the probability of bias from using a single test result. The crushing station was equipped with an Amerclone dry centrifugal dust collector, typical of this type of operation.

Coal Preheating

Emission factors for coal preheaters are based on test data for both furnace and foundry coke plants. Preheater design and operation for foundry coke plants are not fundamentally different from equipment used at furnace coke plants. All of the tests were performed by EPA Method 5 and are rated A or B, depending on the amount of available documentation (several C-rated tests are not incorporated in the emission factors). Test data are available for five of the eight U.S. coke plants equipped with preheaters, and five of the ten preheat systems were tested. All preheater emisson factors are rated C (average) to indicate the use of A- and B-rated test data. Each emission factor is considered to be representative of the designated operation, and no specific bias is apparent. The size specific emission factors were based on tests at a single site, and are rated D to indicate the probability of bias from a small data base.

Wet Coal Charging

Particulate and gaseous emission rates from charging operations have not been extensively measured due to the fugitive nature of the emissions. Limited mass emissions data consisted of two tests of uncontrolled larry car charging, one test of sequential larry car charging, and three tests of scrubber-mounted larry car charging. The test data are C- and D-rated, based on the amount of documentation and the type of test method used. The total mass and size specific emission factors for the wet charging methods are all rated E (poor) to indicate the use of C- and D-rated test data.

Underfiring Combustion Stacks

Emission factors for coke oven underfiring were developed from a large data base. The emission factors for uncontrolled combustion stacks are developed solely from A-rated test data (18 in all) and are rated A (excellent).* The primary process variable affecting uncontrolled emissions is the fuel type. Separate emission factors were developed for underfiring coke oven gas (COG) and blast furnace gas (BFG). Further, the test data for

---

*An additional 68 Test Reports were reviewed but not included in the Emission Factor because of lower ratings (due mainly to the absence of any process information).

underfiring COG were screened to eliminate tests in which desulfurized COG was burned. The desulfurization process is believed to affect the particulate emission as measured by EPA Method 5.

Emisson factors for controlled combustion stacks were developed from A- and B-rated test data. The smaller data base for controlled emissions reflects the use of gas cleaning equipment on only about 10 percent of domestic coke batteries. Both emission factors for controlled combustion are based on underfiring non-desulfurized COG. Both emission factors are rated D (below average) to indicate the probability of bias from using a small data base. Size specific emission factors for uncontrolled combustion stack emissions are based on A- and B-rated test data, and are rated D to indicate the probability of bias from a small data base.

Pushing

Test data were available for a variety of pushing emission control systems. Separate emission factors were developed for four control types--wet ESP, venturi scrubber, baghouse, and mobile scrubber car--and for the uncontrolled situation. Tests were A- and B-rated based on the amount of available documentation. The uncontrolled mass emission factor is based solely on A-rated data, but it is not clear whether a random sample of batteries was obtained, hence the factor is rated B (above average). The mass emission factors for wet ESP and mobile scrubber car controls are based on A- and B-rated data from a reasonable sample of their respective populations, so both are rated C (average). The mass emission factors for baghouse and venturi scrubber controls are based on limited A- and B-rated data and are rated D (below average). The primary process variable affecting particulate emissions, aside from the type of control system used, is the coking time or frequency of "green" pushes. Coking times were not ewell documented in the test data. The type of collection system--shed, travelling hood, or quench car enclosure--also influences the test data, to the extent that emissions are captured. However, there are presently insufficient test data to develop separate emission factors for each collection/control permutation. The size specific emission factors are based on A- and B-rated data, and are rated D to indicate the probability of bias from a small data base.

Door Leaks

Limited test data were available to characterize door leak emissions. A few measurements have been made with a local hood, and under a cokeside shed during nonpushing periods. These tests were A- and B-rated based on the amount of available documentation. The door leak emission factor is rated D (below average) to indicate the probability of bias from a small data base.

Quenching

Particulate emissions from coke quenching have been measured for a reasonable number of controlled (baffled) quench towers. However, only limited data from one test series are available for the uncontrolled situation. All of the test data were A-rated. Emission factors were developed separately for quenching with clean water (TDS 1500mg/1), and with dirty water (TDS 5000 mg/1), since water quality has been found to have a major influence on particulate emissions.

The controlled emission factors are rated B (above average), since the test data represent a reasonable number of facilities but are not clearly a random sample. The uncontrolled emission factors are rated D (below average) to indicate the probability of bias from using a single test result. The size specific emission factors were based on tests at a single site, and are rated D to indicate the probability of bias from a small data base.

Coke Handling

Particulate emissions from coke handling have not been widely measured due to their fugitive nature. Three separate tests of two crushing and screening stations were available. Each station is equipped with a cyclone control device. The tests are B-rated based on the documentation available and the resultant emission factor is rated D (below average) to indicate the probability of bias from a small data base.

REFERENCES

1. Stack Test Report for Bethlehem Steel Corp., Bethlehem, Pennsylvania, PADER, September 1978, JACA file.

2. Stack Test Report for Allied Chemical Co., Semet Solvay Division, Detroit, Michigan, ERG Inc., July 1978, RACT Box (512635-512672).

3. Stack Test Report for Allied Chemical Co., Semet Solvay Division, Detroit, Michigan, ERG Inc., RACT Box (512591-512634).

4. Stack Test Report for Inland Steel Co., E. Chicago, Indiana, Environmental Instrument Systems, August 1977, RACT Box (512991-513062).

5. Stack Test Report for J&L Steel Co., Aliquippa, Pennsylvania, Betz Environmental Engineers, April 1977, RACT Box (513063-513310).

6. Stack Test Report for J&L Steel Co., Aliquippa, Pennsylvania, August 1978, RACT Box (512673-512990).

7. Stack Test Report for Alabama Byproducts, Tarrant City, Alabama, Guardian Systems, April 1980, JACA file.

8. Stack Test Report for J&L Steel Co., Aliquippa, Pennsylvania, PADER, November 1977, JACA file.

9. Stack Test Report for U.S. Steel Co., Gary, Indiana, Clean Air Engineering, July 1978, JACA file.

10. Stack Test Report, Bethlehem Steel Co., Burns Harbor, Indiana, Bethlehem Steel, April 1970, JACA file.

11. R. W. Bee et al, Coke Oven Charging Emission Control Test Program, Volume I, EPA-650/2-74-062 (NTIS No. PB 237628), U. S. Environmental Protection Agency, Washington, DC, July 1974.

12. A.R. Trenholm, International Trip Report, February 18, 1976. Tests at: a) Ruhrkohle Zollverein, date unknown; b) Osterfeld, August 1974.

13. Particulate Emissions Factors Applicable to the Iron & Steel Industry. EPA-450/4-79-028 (NTIS No. PB 81-145914) U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1979.

14. Stack Test Report for Bethlehem Steel Co., Sparrows Point, Maryland, Maryland Bureau of Air Quality and Noise Control, July 1975, JACA file.

15. Stack Test Report for Ford Motor Co., Dearborn, Michigan, November 1981, JACA file.

16. Stack Test Report for National Steel, Granite City, Illinois, United McGill Co., October 1979, JACA file.

17. Stack Test Report for Shenango Steel, Inc., Neville Island, Pennsylvania, Betz Environmental Engineers, July 1976, JACA file.

18. Stack Test Report for U.S. Steel Co., Gary, Indiana, Clean Air Engineering, July 1978, JACA file.

19. Stack Test Report, U.S. Steel Co., Gary, Indiana, U.S. Steel, April 1981, JACA file.

20. Stack Test Report, U.S. Steel Co., Gary, Indiana, U.S. Steel, November 1981, JACA file.

21. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 15), CH_2M Hill, March 1980, JACA file.

22. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 16), CH_2M Hill, April 1980, JACA file.

23. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 7), CH_2M Hill, April 1980, JACA file.

24. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 5), CH_2M Hill, April 1980, JACA file.

25. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 5), CH_2M Hill, May 1980, JACA file.

26. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 3), CH_2M Hill, June 1980, JACA file.

27. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 16), CH_2M Hill, JACA file.

28. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 16), CH_2M Hill, July 1980, JACA file.

29. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 5), CH_2M Hill, July 1980, JACA file.

30. Stack Test Report for U.S. Steel Co., Gary, Indiana, (Combustion Stack Battery No. 7), CH_2M Hill, July 1980, JACA file.

31. Stack Test Report for U.S. Steel Co., Provo, Utah, (Combustion Stack Battery No. 4), TETCO, February 1981, JACA file.

32. Stack Test Report for U.S. Steel Co., Provo, Utah, (Combustion Stack Battery No. 3), EEMC, February 1981, JACA file.

33. Stack Test Report for U.S. Steel Co., Provo, Utah, (Combustion Stack Battery No. 2), TETCO, February 1982, JACA file.

34. Stack Test Report for U.S. Steel Co., Provo, Utah, (Combustion Stack Battery No. 1), TETCO, October 1981, JACA file.

35. Stack Test Report, U.S. Steel Co., Clairton, Pennsylvania, (Combustion Stack Battery No. 21), U.S. Steel, December 1979, JACA file.

36. Stack Test Report for U.S. Steel Co., Clairton, Pennsylvania, (Combustion Stack Battery No. 21), U.S. Steel, September 1981, JACA file.

37. Stack Test Report for Republic Steel Co., Cleveland, Ohio, Acurex Corp., July 1979, JACA file.

38. Stack Test Report for Kaiser Steel, Fontana, California, Engineering Science, January 1980, JACA file.

39. Stack Test Report for Armco Steel Corp., Houston, Texas, Southwestern Lab., October 1976 and August 1977, JACA file.

40. Stack Test Report for Armco Steel Corp., Houston, Texas, Southwestern Lab., May 1, 1979, JACA file.

41. Stack Test Report for Armco Steel Corp., Houston, Texas, Southwestern Lab., May 2-3, 1979, JACA file.

42. Stack Test Report for Armco Steel Corp., Houston, Texas, Southwestern Lab., July 1979, JACA file.

43. Stack Test Report, Bethlehem Steel, Bethlehem, Pennsylvania, Bethlehem Steel, December 1980, JACA file.

44. Stack Test Report, Bethlehem Steel, Burns Harbor, Indiana, Bethlehem Steel, September 1974, JACA file.

45. Stack Test Report for Ford Motor Co., Dearborn, Michigan, February 1982, JACA file.

46. Stack Test Report for Ford Motor Co., Dearborn, Michigan, July 1979, JACA file.

47. Stack Test Report for Great Lakes Carbon Corp., St. Louis, Missouri, Clayton Environmental Services, June 1976, JACA file.

48. Stack Test Report for Interlake, Inc., Chicago, Illinois, June 1980, JACA file.

49. Stack Test Report for DOFASCO, Ltd., Hamilton, Ontario, Envirocon Report TE2612, March 1979.

50. Stack Test Report for Allied Chemical Corp., Ashland, Kentucky, York Research Corp., April 1979, JACA file.

51. Source Testing of a Stationary Coke-Side Enclosure, Bethlehem Steel, Burns Harbor Plant, EPA-340/1-76-012 (NTIS No. PB 270686), U.S. Environmental Protection Agency, Washington, DC, May 1977.

52. Stack Test Report, U.S. Steel, Gary, Indiana, (Battery No. 9), U.S. Steel, October 1981.

53. Stack Test Report, U.S. Steel Co., Gary, Indiana, U.S. Steel, (Batteries 13, 15 and 16), October 1981.

54. Stack Test Report for Wheeling Pittsburgh Steel Co., Monassen, Pennsylvania, August 1981, RACT Box.

55. File of D. Bakk, EPA Region V, Republic Steel Batteries 21 and 22, Bethlehem Steel Battery No. 5.

56. Phone conversation with Cliff Brown, Republic Steel, re: Republic Steel, Warren and Youngstown, Ohio plants. Tests of Warren Battery 4 and Youngstown Batteries B and C, October 1981.

57. Particulate Emission Evaluation of the Envirotech/Chemico Spot Quench Car System at P-4 Coke Oven Battery of Jones & Laughlin Steel Corporation, Pittsburgh, Pennsylvania, September 1979.

58. Stack Test Report, Bethlehem Steel Co., Sparrows Point, Maryland, Bethlehem Steel, September 1980, JACA file.

59. Particulate Emission Evaluation of the Envirotech/Chemico One Spot Quench Car at the H-4 and H-9 Coke Oven Batteries of Jones & Laughlin Steel Corporation, East Chicago, Illinois, May 1981.

60. Stack Test Report, U.S. Steel Co., Clairton, Pennsylvania, U.S. Steel, August 1981, RACT Box.

61. Stack Test Report, U.S. Steel Co., Clairton, Pennsylvania, U.S. Steel, April 1981, RACT Box.

62. Stack Test Report, Republic Steel Co., Cleveland, Ohio, Republic Steel, November 1979, JACA file.

63. Stack Test Report, Republic Steel Co., Cleveland, Ohio, Republic Steel, June 1979, JACA file.

64. Stack Test Report, U.S. Steel Co., Fairfield, Alabama, U.S. Steel, June 1979, JACA file.

65. Stack Test Report, Bethlehem Steel Co., Sparrows Point, Maryland, Bethlehem Steel, October 1980, RACT Box.

66. Stack Test Report, Bethlehem Steel Co., Johnstown, Pennsylvania, Bethlehem Steel, May 1979, JACA file.

67. Stack Test Report, Bethlehem Steel Co., Sparrows Point, Maryland, Bethlehem Steel, November 1980, JACA file.

68. Stack Test Report for CF&I, Pueblo, Colorado, March 1980, JACA file.

69. Stack Test Report, Inland Steel Co., East Chicago, Illinois, Inland Steel, November 1978, JACA file.

70. Stack Test Report, Inland Steel Co., East Chicago, Illinois, Inland Steel, December 1979, JACA file.

71. Stack Test Report, Inland Steel Co., East Chicago, Illinois, Inland Steel, June 1980, JACA file.

72. Stack Test Report for Great Lakes Carbon, April 1975, JACA file.

73. Stack Test Report, Bethlehem Steel Co., Burns Harbor, Indiana, Bethlehem Steel, March 1975, JACA file.

74. A.H. Laube and J. D. Jeffery, "Draft Report Quench Tower Emission Tests USS Lorain Quench Tower No. 1.", October 1976.

75. "Report on Emissions Tests Conducted on Quench Towers No. 3 and No. 5 and Quench Tower Air Quality Impact Modeling at U.S. Steel Corporation, Gary, Indiana," Volumes I and II, TRC Environmental Consultants, Inc., January 1980.

76. J. Jeffery, Wet Coke Quench Tower Emission Factor Development, DOFASCO Ltd., EPA-600/X-85-340, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1982.

77. Stack Test Report, Bethlehem Steel Co., Bethlehem, Pennsylvania, Bethlehem Steel, September 1978, JACA file.

78. Stack Test Report for J&L Steel Co., Pittsburgh, Pennsylvania, Wheelabrator-Frye, Inc., April 1980, JACA file.

79. Stack Test Report for J&L Steel Co., Pittsburgh, Pennsylvania, Mostardi-Platt Assoc., June 1980, JACA file.

80. Emission Testing & Evaluation of Ford/Koppers Coke Pushing Control System, Volume 2, Appendices, EPA-600/2-77-187b (NTIS No. PB 277076), U.S. Environmental Protection Agency, Washington, DC, July 1974.

81. Stack Test Report for Inland Steel, East Chicago, Indiana, Betz Environmental Engineeers, June 1976, JACA file.

82. Air Pollution by Coking Plants, United Nations Report: Economic Commission for Europe, ST/ECE/Coal/26, 1968.

83. R. W. Fullerton, "Impingement Baffles to Reduce Emissions from Coke Quenching, "Journal of the Air Pollution Control Association, 17:807-809, December 1967.

84. J. Varga, Jr., and H. W. Lownie, Jr., Final Technological Report on a Systems Analysis Study of the Integrated Iron and Steel Industry, EPA Report APTD 1279 (NTIS No. PB 184577), U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1969.

SECTION 4

PROPOSED AP-42 SECTION

7.2 COKE MANUFACTURING

7.2.1 Process Description

Metallurgical coke is manufactured by destructive distillation of coal in a byproduct coke oven battery. The distillation, termed "coking", is accomplished in a series of ovens in the absence of oxygen. Volatile compounds are driven from the coal, collected from each oven, and processed in an adjacent plant for recovery of combustible gases and other coal byproducts. Virtually all metallurgical coke is produced by this process, termed the "byproduct" method. Metallurgical coke is used in blast furnaces for production of iron.

Coke is produced in narrow, slot type ovens constructed of silica brick. A coke oven battery may have a series of 10 to 100 individual ovens, with a heating flue between each oven pair. Ovens are charged with pulverized coal, through ports in the oven top, by a larry car traveling on tracks along the top of each battery. After charging, the ports are sealed, and the coking process begins. Combustion of gases in burners in the flues between the ovens provides heat for the process. Coke oven gas from the byproduct recovery plant is the common fuel for underfiring the ovens at most plants, but blast furnace gas and, infrequently, natural gas may also be used.

After a coking time typically between 12 and 20 hours, almost all volatile matter is driven from the coal mass, and the coke is formed. Maximum temperature at the center of the coke mass is usually 1100 to 1150°C (2000 to 2100°F).

After coking, machinery located on tracks on each side of the battery removes the vertical door on each end of an oven, and a long ram pushes the coke from the oven into a rail quench car, whence it goes to a quench tower, where several thousand gallons of water are sprayed onto the coke mass to cool it. The car then discharges the coke onto a wharf along the battery for further cooling and drainage of water. From here, coke is screened and sent to the blast furnace or to storage in outdoor piles.

After the coke is pushed from an oven, the doors are cleaned and repositioned, and the oven is then ready to receive another charge of coal. Figure 7.2-1 is a diagram of a typical byproduct coke process.

During the coking cycle, volatile matter driven from the coal mass is collected by offtakes located at one or both ends of the oven. A common collector main transports the gases from each oven to the byproduct recovery plant. Here, coke oven gas is separated, cleaned and returned to heat the ovens. Only 40 percent of recovered coke oven gas is required for underfiring, and the remainder is used throughout the steel plant. Other coal byproducts also are recovered in the byproduct plant for reuse, sale or disposal.

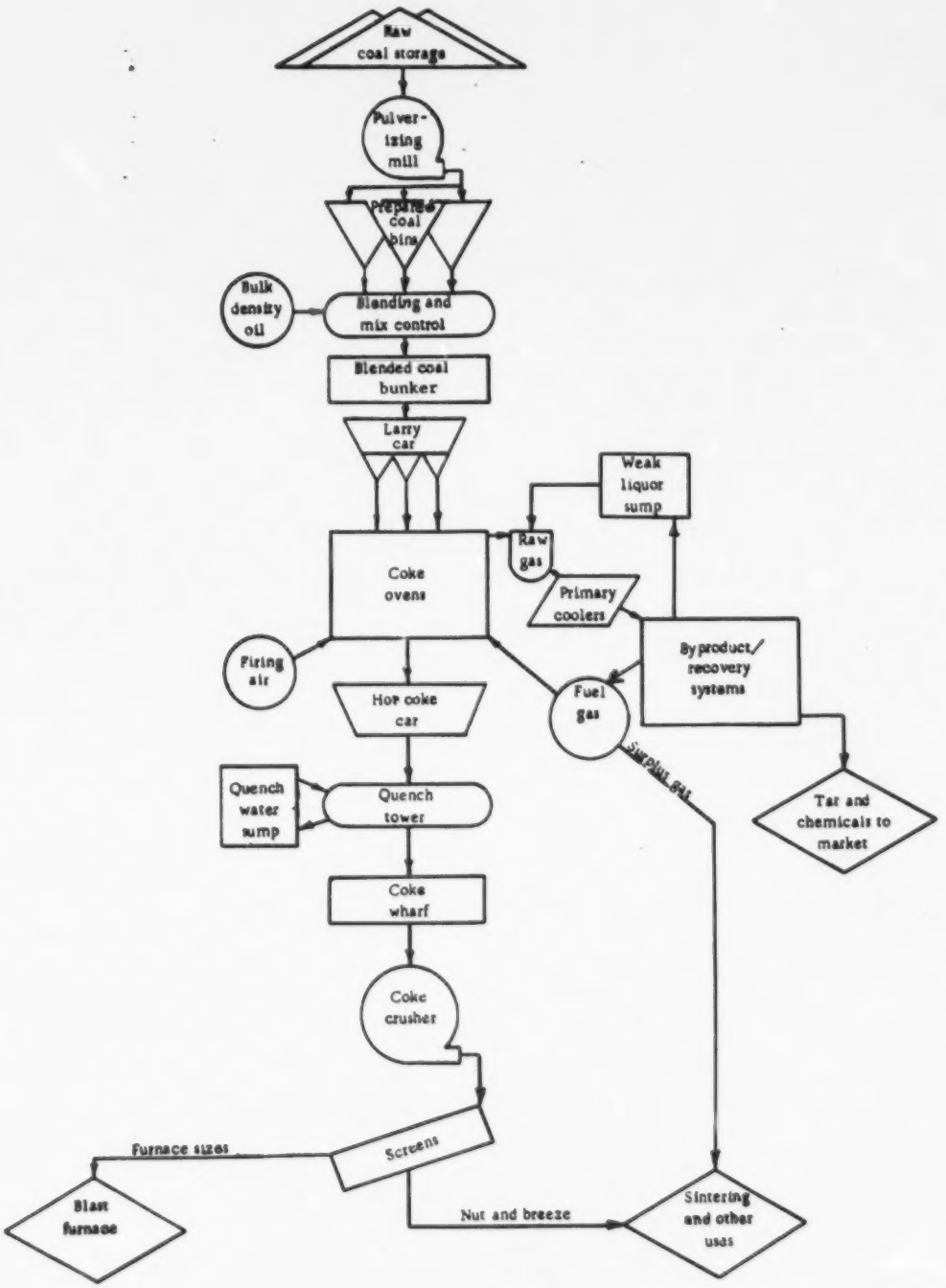


Figure 7.2-1. The major steps in the carbonization of coal with the byproduct process.

7.2.2 Emissions And Controls

Particulate, volatile organic compounds, carbon monoxide and other emissions originate from several byproduct coking operations: (1) coal preparation, (2) coal preheating (if used), (3) charging coal into ovens incandescent with heat, (4) oven leakage during the coking period, (5) pushing the coke out of the ovens, (6) quenching the hot coke and (7) underfire combustion stacks. Gaseous emissions collected from the ovens during the coking process in the byproduct plant are subjected to various operations for separating ammonia, coke oven gas, tar, phenol, light oil (benzene, toluene, xylene) and pyridine. These unit operations are potential sources of volatile organic compound emissions.

Coal preparation consists of pulverizing, screening, blending of several coal types, and adding oil or water for bulk density control. Particulate emissions are sometimes controlled by evacuated or unevacuated enclosures. A few domestic plants heat coal to about 260°C (500°F) before charging, using a flash drying column heated by combustion of coke oven or natural gas. The air steam that conveys the coal through the drying column usually is passed through conventional wet scrubbers for particulate removal before discharge to the atmosphere.

Oven charging can produce emissions of particulate matter and volatile organic compounds from coal decomposition. The stage, or sequential, charging techniques used on virtually all batteries draw most charging emissions into the battery collector main and on to the byproduct plant. During the coking cycle, volatile organic emissions from the thermal distillation process occasionally leak to the atmosphere through poorly sealed doors, charge lids and offtake caps, and through cracks which may develop in oven brickwork, the offtakes and collector mains. Door leaks are controlled by diligent door cleaning and maintenance, rebuilding of doors, and in some plants, by manual application of lute (seal) material. Charge lid and offtake leaks are controlled by an effective patching and luting program.

Pushing coke into the quench car is another major source of particulate emissions, and if the coke mass is not fully coked, also of volatile organic compounds and combustion products. Most batteries use pushing emission controls such as hooded, mobile scrubber cars; shed enclosures evacuated to a gas cleaning device; or traveling hoods with a fixed duct leading to a stationary gas cleaner. The quench tower activity emits particulate from the coke mass, and dissolved solids from the quench water may become entrained in the steam plume rising from the tower. Trace organic compounds also may be present.

The gas combustion in the battery flues produces emissions through the underfire or combustion stack. If coke oven gas is not desulfurized, sulfur oxide emissions accompany the particulate and combustion emissions. If oven wall brickwork is damaged, coal fines and coking decomposition products from a recently charged oven may leak into the waste combustion gases. Figure 7.2-2 portrays major air pollution sources from a typical coke oven battery.

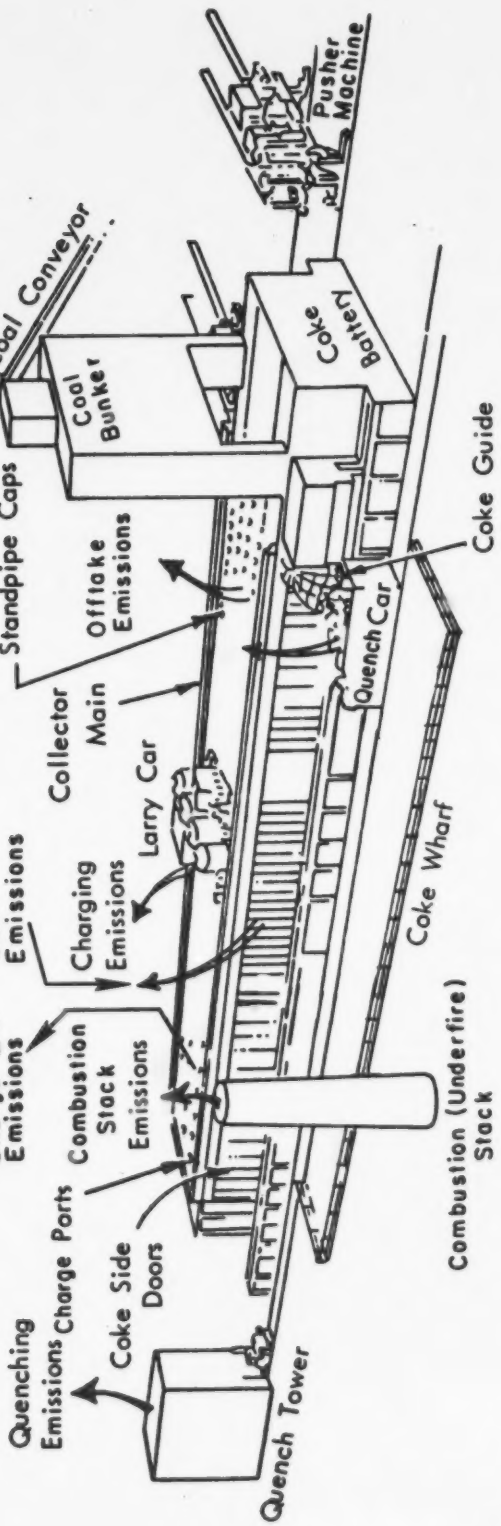


Figure 7.2-2. Byproduct coke oven battery, with major emission points shown.

Associated with the byproduct coke production are open source fugitive dust operations from material handling. These operations consist of unloading, storing grinding and sizing of coal; and screening, crushing, storing and loading of coke. Fugitive emissions may also result from vehicles traveling on paved and unpaved surfaces. The emission factors available for coking operations for total particulate, sulfur dioxide, carbon monoxide, volatile organic compounds, nitrogen oxides and ammonia are given in Table 7.2-1. Table 7.2-2 gives available size specific emission factors. Figures 7.2-3 through 7.2-13 present emission factor data by particle size. Extensive information on the data used to develop the particulate emission factors can be found in Reference 1.

TABLE 7.2-1. EMISSION FACTORS FOR COKE MANUFACTURING[a]

Type of operation	Particulate Emission Factor Rating[b]	Particulate[b]		Sulfur dioxide[c]		Carbon monoxide[c]		Volatile organics[c,d]		Nitrogen oxides[c]		Ammonia[c]	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Coal crushing													
with cyclone	D	0.055	0.11	-	-	-	-	-	-	-	-	-	-
Coal preheating													
Uncontrolled[e]	C	1.75	3.50	-	-	-	-	-	-	-	-	-	-
With scrubber	C	0.125	0.25	-	-	-	-	-	-	-	-	-	-
With wet ESP	C	0.006	0.012	-	-	-	-	-	-	-	-	-	-
Wet coal charging[f]													
Larry car													
Uncontrolled	E	0.24	0.48	0.01	0.02	0.3	0.6	1.25	2.5	0.015	0.03	0.01	0.02
With sequential charging	E	0.008	0.016	-	-	-	-	-	-	-	-	-	-
With scrubber	E	0.007	0.014	-	-	-	-	-	-	-	-	-	-
Door leak													
Uncontrolled	D	0.27	0.54	-	-	0.3	0.6	0.75	1.5	0.005	0.01	0.03	0.06
Coke pushing													
Uncontrolled	B	0.58	1.15	-	-	0.035	0.07	0.1	0.2	-	-	0.05	0.1
With ESP[g]	C	0.225	0.45	-	-	-	-	-	-	-	-	-	-
With venturi scrubber[h]	D	0.09	0.18	-	-	-	-	-	-	-	-	-	-
With baghouse[h]	D	0.045	0.09	-	-	-	-	-	-	-	-	-	-
With mobile scrubber car[j]	C	0.036	0.072	-	-	-	-	-	-	-	-	-	-

TABLE 7.2-1 (cont.). EMISSION FACTORS FOR COKE MANUFACTURING[a]

Type of operation	Particulate Emission Factor Rating[b]	Particulate[b]		Sulfur dioxide[c]		Carbon monoxide[c]		Volatile organics[c,d]		Nitrogen oxides[c]		Ammonia[c]	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Quenching													
Uncontrolled													
Dirty water[k]	D	2.62	5.24	-	-	-	-	-	-	-	-	-	-
Clean water[m]	D	0.57	1.13	-	-	-	-	-	-	-	-	-	-
With baffles													
Dirty water[k]	B	0.65	1.30	-	-	-	-	-	-	-	-	-	-
Clean water[m]	B	0.27	0.54	-	-	-	-	-	-	-	-	-	-
Combustion stack													
Uncontrolled (COG)	A	0.234	0.47	2.0[n]	4.0[n]	-	-	-	-	-	-	-	-
Uncontrolled (BFG)	A	0.085	0.17	-	-	-	-	-	-	-	-	-	-
With ESP (COG)	D	0.046	0.091	-	-	-	-	-	-	-	-	-	-
With baghouse (COG)	D	0.055	0.11	-	-	-	-	-	-	-	-	-	-
Coke handling													
With cyclone[p]	D	0.003	0.006	-	-	-	-	-	-	-	-	-	-
Combined operations[q]	D	-	-	-	-	-	-	-	-	-	-	-	-

[a]Expressed as units/unit of coal charged. Dash = no data. ESP = electrostatic precipitator. COG = coke oven gas. BFG = blast furnace gas.
[b]Reference 1.
[c]References 2-3.
[d]Expressed as methane.
[e]Exhaust gas discharged from series of primary and secondary cyclones used to separate flash dried coal from hot gas.
[f]Charged coal has not been dried.
[g]Emissions captured by coke side shed.
[h]Emissions captured by traveling hood.
[j]Emissions captured by quench car enclosure.
[k]Dirty water $\geq$5000 mg/l total dissolved solids.
[m]Clean water $\leq$1500 mg/l total dissolved solids.
[n]Reference 4. Factor for SO_2 is based on these representative conditions: (1) sulfur content of coal charged to oven is 0.8 weight %; (2) about 33 weight % of total sulfur in coal charged to oven is transferred to coke oven gas; (3) about 40% of coke oven gas is burned during underfiring operation, and about 60% is used in other operations where the rest of the SO_2 [3 kg/Mg (6 lb/ton) of coal charged] is discharged; (4) gas used in underfiring has not been desulfurized.
[p]Defined as crushing and screening.
[q]References 19-20. Uncontrolled lead emissions are 0.00018 kg/Mg (0.00035 lb/ton).

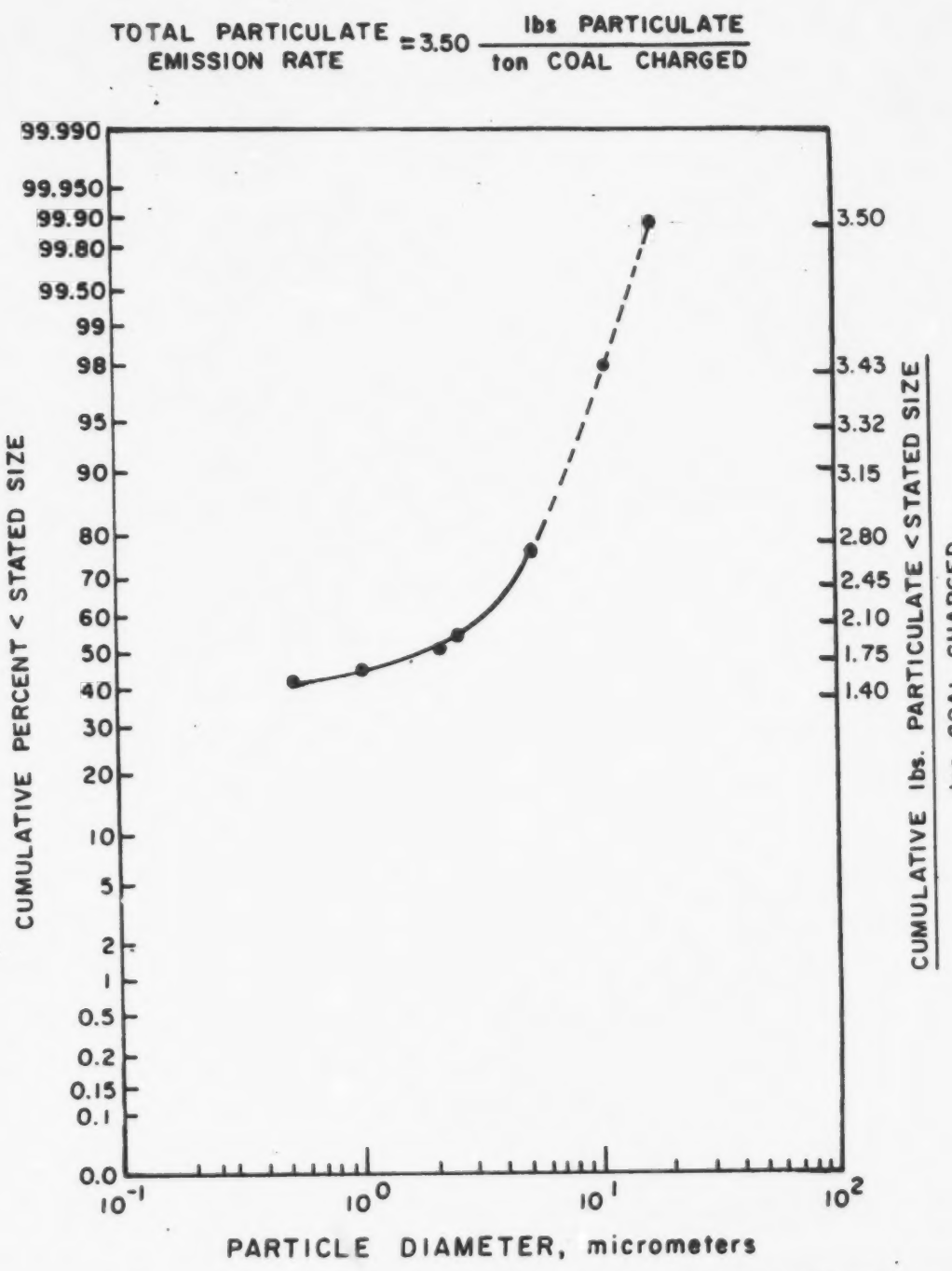
TABLE 7.2-2. SIZE SPECIFIC EMISSION FACTORS FOR COKE MANUFACTURING

Process	Particulate emission factor rating	Particle size (μm)	Cumulative mass % ≤ stated size	Cumulative mass emission factors kg/Mg	Cumulative mass emission factors lb/ton	Reference source number
Coal preheating Uncontrolled	D	0.5	44	0.8	1.5	6
		1.0	48.5	0.8	1.7	
		2.0	55	1.0	1.9	
		2.5	59.5	1.0	2.1	
		5.0	79.5	1.4	2.8	
		10.0	97.5	1.7	3.4	
		15.0	99.9	1.7	3.5	
			100	1.7	3.5	
Controlled with venturi scrubber	D	0.5	78	0.10	0.20	6
		1.0	80	0.10	0.20	
		2.0	83	0.10	0.21	
		2.5	84	0.11	0.21	
		5.0	88	0.11	0.22	
		10.0	94	0.12	0.24	
		15.0	96.5	0.12	0.24	
			100	0.12	0.25	
Coal charging Sequential or stage	E	0.5	13.5	0.001	0.002	7
		1.0	25.2	0.002	0.004	
		2.0	33.6	0.003	0.005	
		2.5	39.1	0.003	0.006	
		5.0	45.8	0.004	0.007	
		10.0	48.9	0.004	0.008	
		15.0	49.0	0.004	0.008	
			100	0.008	0.016	
Coke pushing Uncontrolled	D	0.5	3.1	0.02	0.04	8-13
		1.0	7.7	0.04	0.09	
		2.0	14.8	0.09	0.17	
		2.5	16.7	0.10	0.19	
		5.0	26.6	0.15	0.30	
		10.0	43.3	0.25	0.50	
		15.0	50.0	0.29	0.58	
			100	0.58	1.15	
Controlled with Venturi scrubber	D	0.5	24	0.02	0.04	8,10
		1.0	47	0.04	0.08	
		2.0	66.5	0.06	0.12	
		2.5	73.5	0.07	0.13	
		5.0	75	0.07	0.13	
		10.0	87	0.08	0.16	
		15.0	92	0.08	0.17	
			100	0.09	0.18	

(continued)

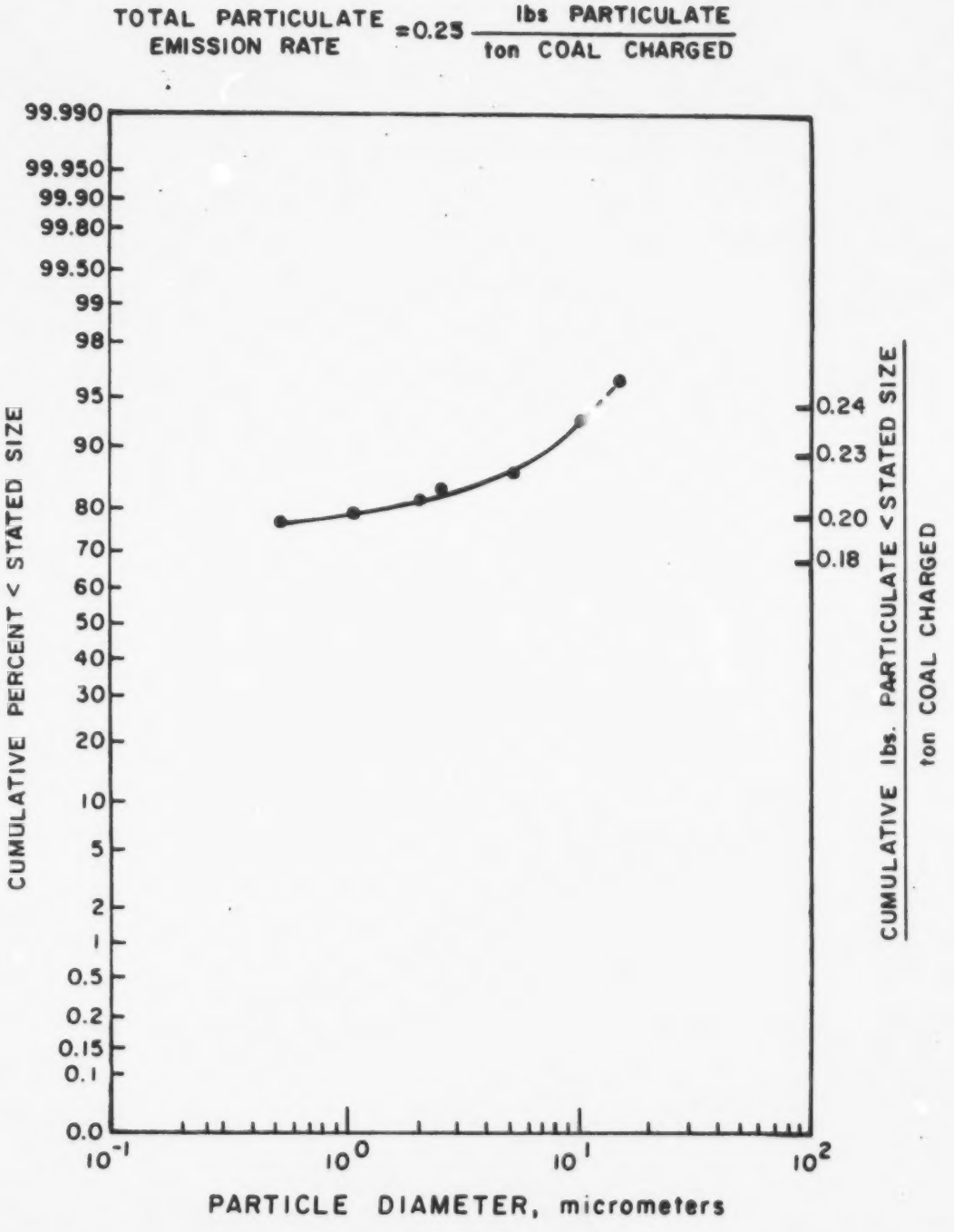
TABLE 7.2-2 (continued)

Process	Particulate emission factor rating	Particle size (μm)	Cumulative mass % ≤ stated size	Cumulative mass emission factors kg/Mg	Cumulative mass emission factors lb/ton	Reference source number
Mobile scrubber car	D	1.0	28.0	0.010	0.020	14
		2.0	29.5	0.011	0.021	
		2.5	30.0	0.011	0.022	
		5.0	30.0	0.011	0.022	
		10.0	32.0	0.012	0.024	
		15.0	35.0	0.013	0.023	
			100	0.036	0.072	
Quenching Uncontrolled (dirty water)	D	1.0	13.8	0.36	0.72	15
		2.5	19.3	0.51	1.01	
		5.0	21.4	0.56	1.12	
		10.0	22.8	0.60	1.19	
		15.0	26.4	0.69	1.38	
			100	2.62	5.24	
Uncontrolled (clean water)	B	1.0	4.0	0.02	0.05	15
		2.5	11.1	0.06	0.13	
		5.0	19.1	0.11	0.22	
		10.0	30.1	0.17	0.34	
		15.0	37.4	0.21	0.42	
			100	0.57	1.13	
With baffles (dirty water)	D	1.0	8.5	0.06	0.11	15
		2.5	20.4	0.13	0.27	
		5.0	24.8	0.16	0.32	
		10.0	32.3	0.21	0.42	
		15.0	49.8	0.32	0.65	
			100	0.65	1.30	
With baffles (clean water)	D	1.0	1.2	0.003	0.006	15
		2.5	6.0	0.02	0.03	
		5.0	7.0	0.02	0.04	
		10.0	9.8	0.03	0.05	
		15.0	15.1	0.04	0.08	
			100	0.27	0.54	
Combustion stack Uncontrolled	D	1.0	77.4	0.18	0.36	16-18
		2.0	85.7	0.20	0.40	
		2.5	93.5	0.22	0.44	
		5.0	95.8	0.22	0.45	
		10.0	95.9	0.22	0.45	
		15.0	96	0.22	0.45	
			100	0.23	0.47	



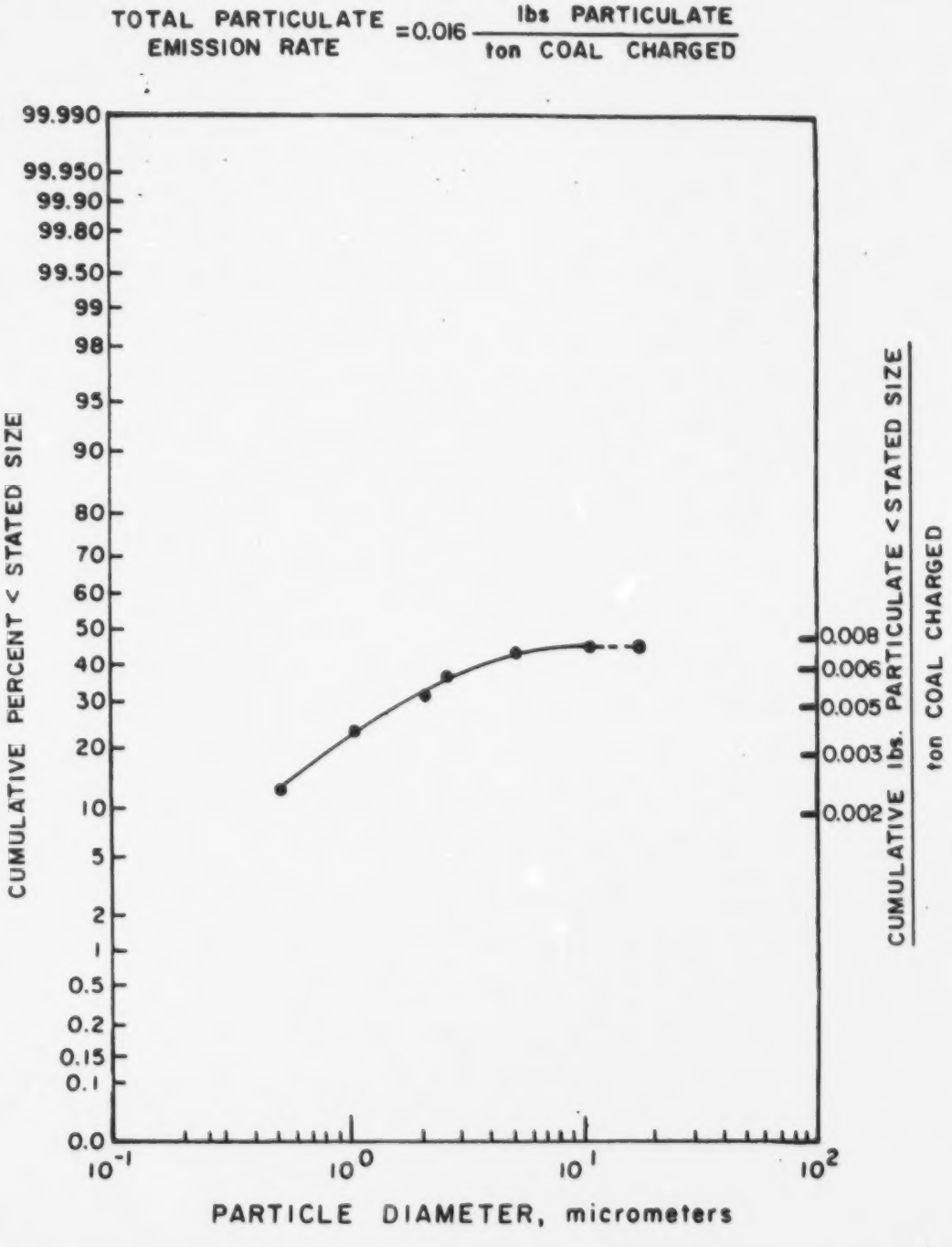
Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-3. Coal preheating (uncontrolled).



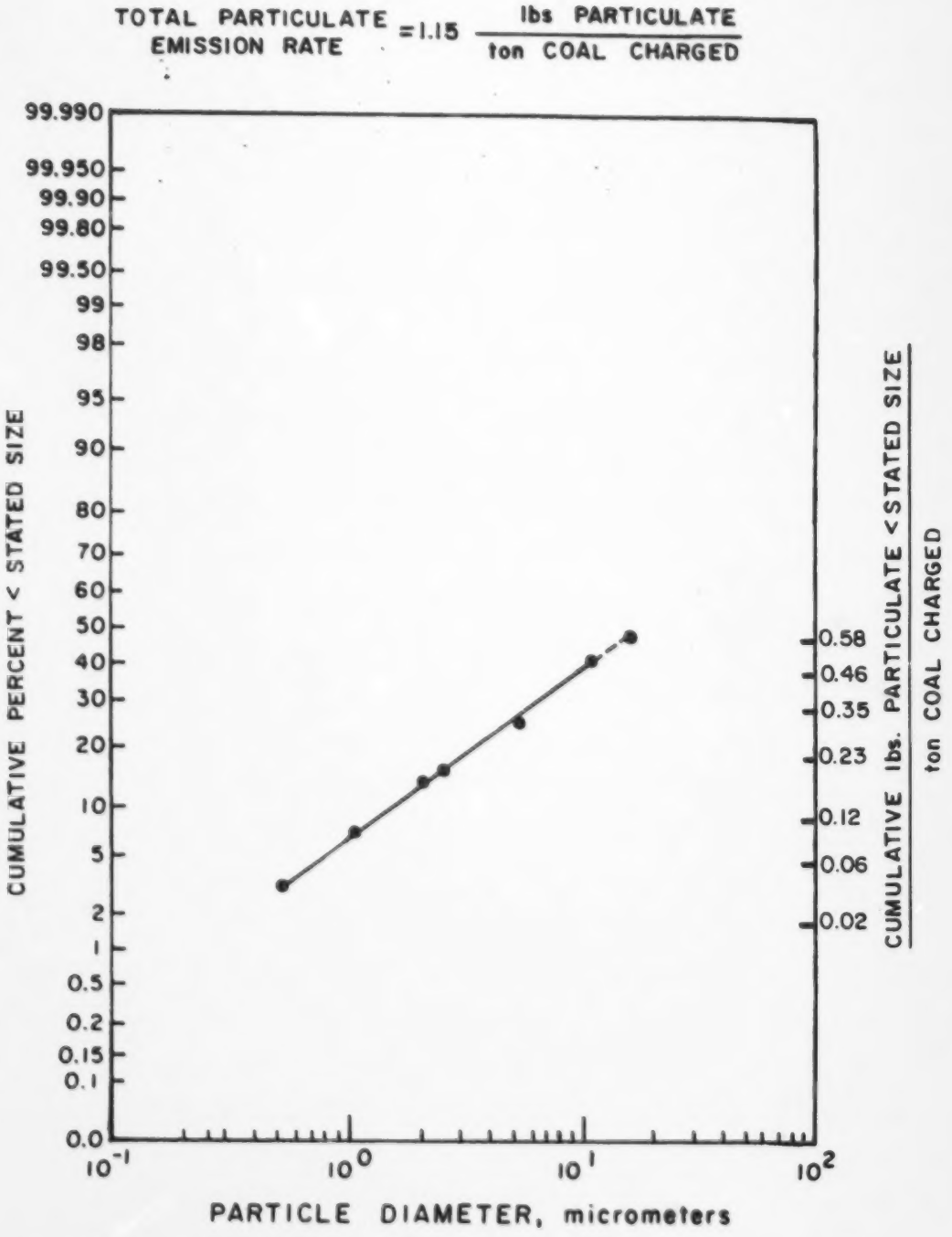
Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-4. Coal preheating (controlled with scrubber).



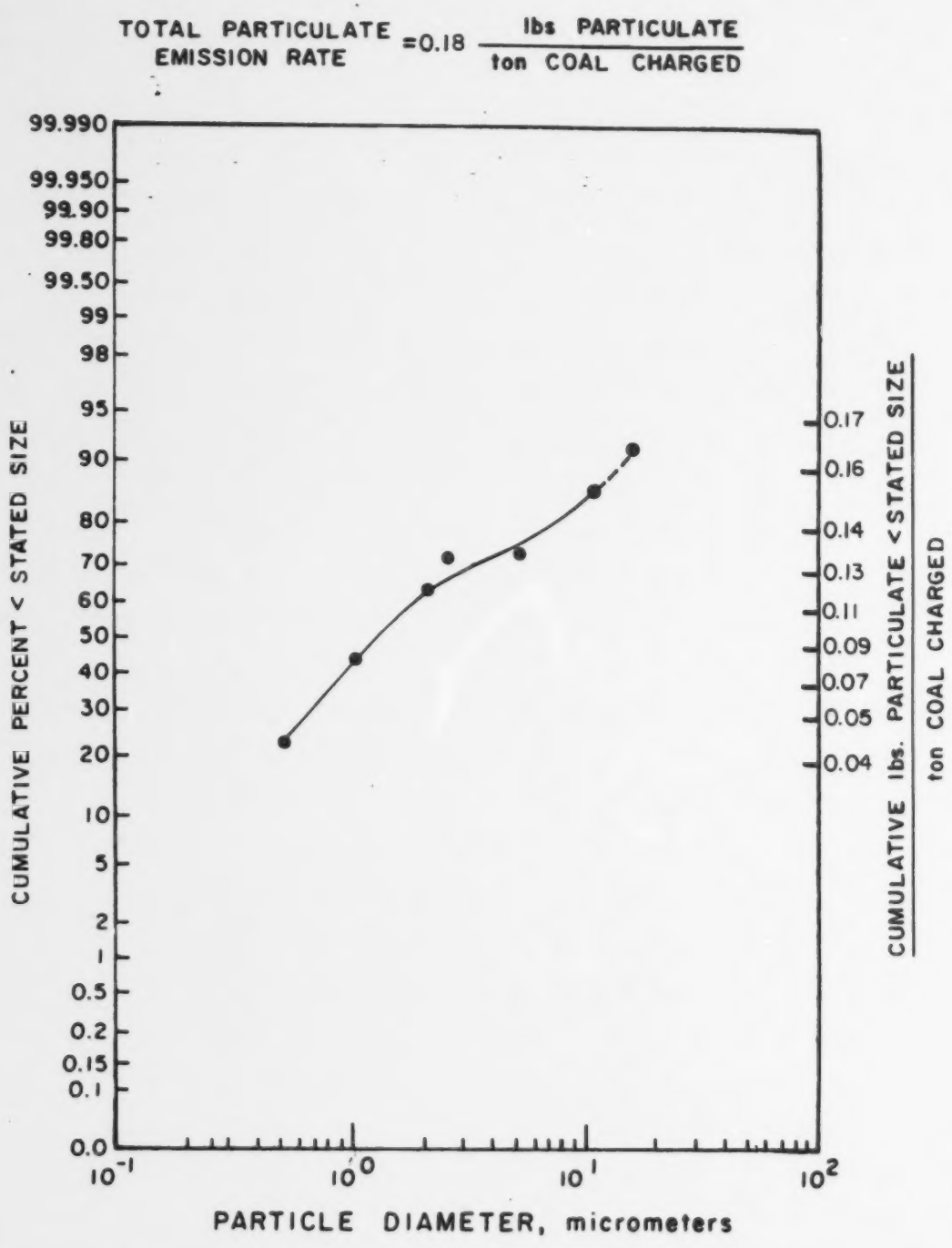
Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-5. Coal charging (sequential) average of 2 tests.



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-6. Pushing (uncontrolled) average of 6 sites.



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-7. Pushing (controlled with scrubber) average of 2 sites.

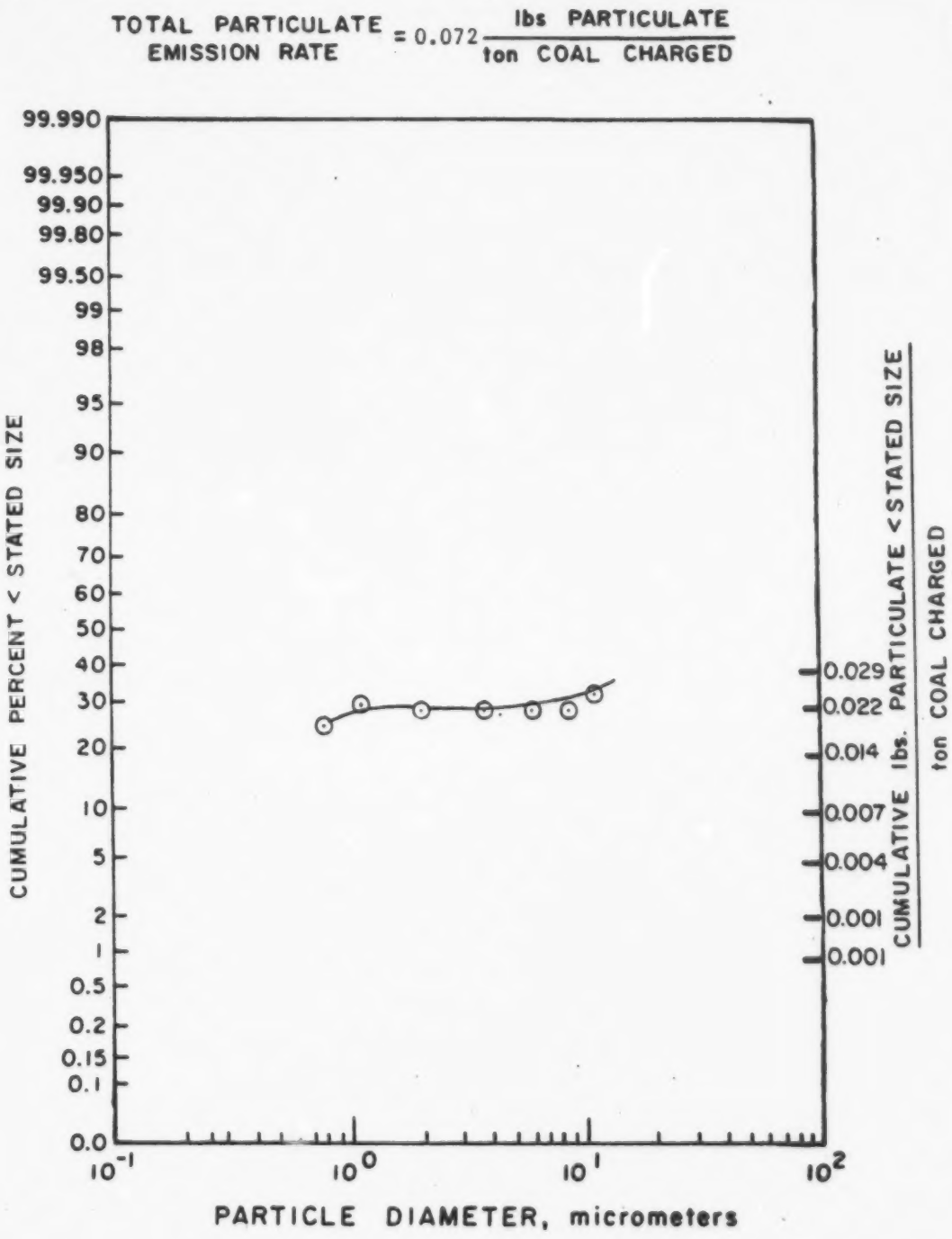


Figure 7.2-8. Mobile scrubber cars.

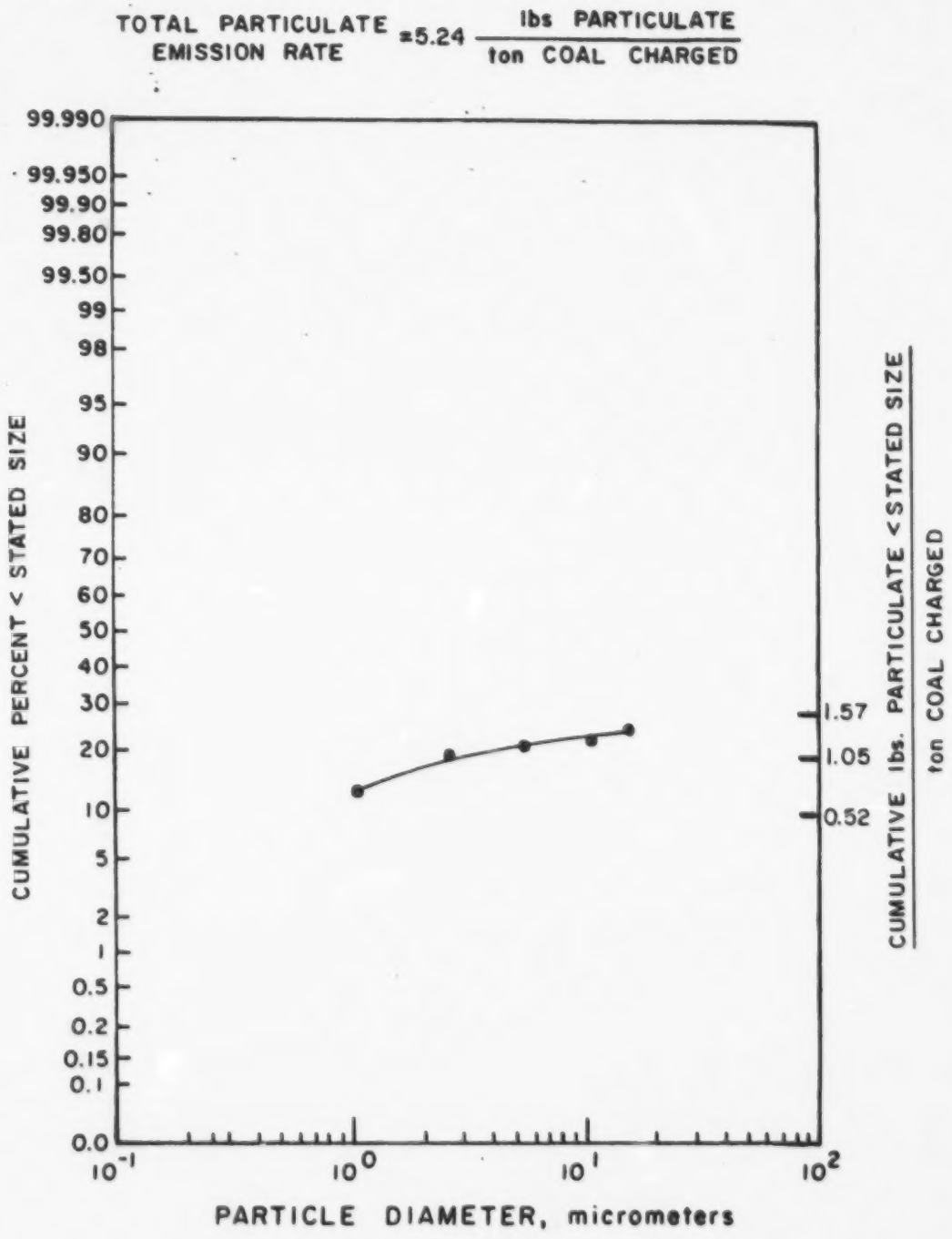


Figure 7.2-9. Quenching (uncontrolled) dirty water >5,000 mg/L TDS.

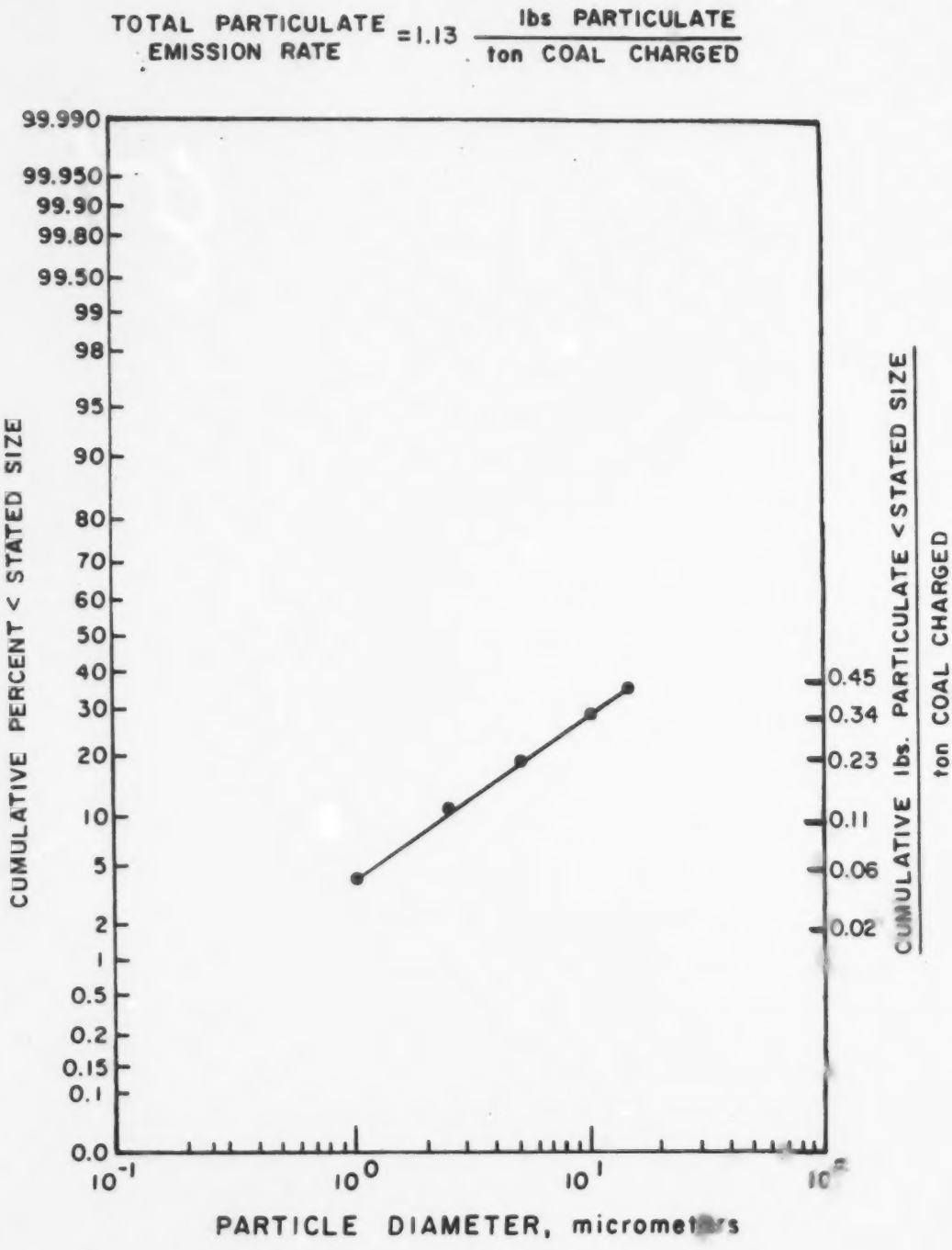


Figure 7.2-10. Quenching (uncontrolled) clean water <1,500 mg/L TDS.

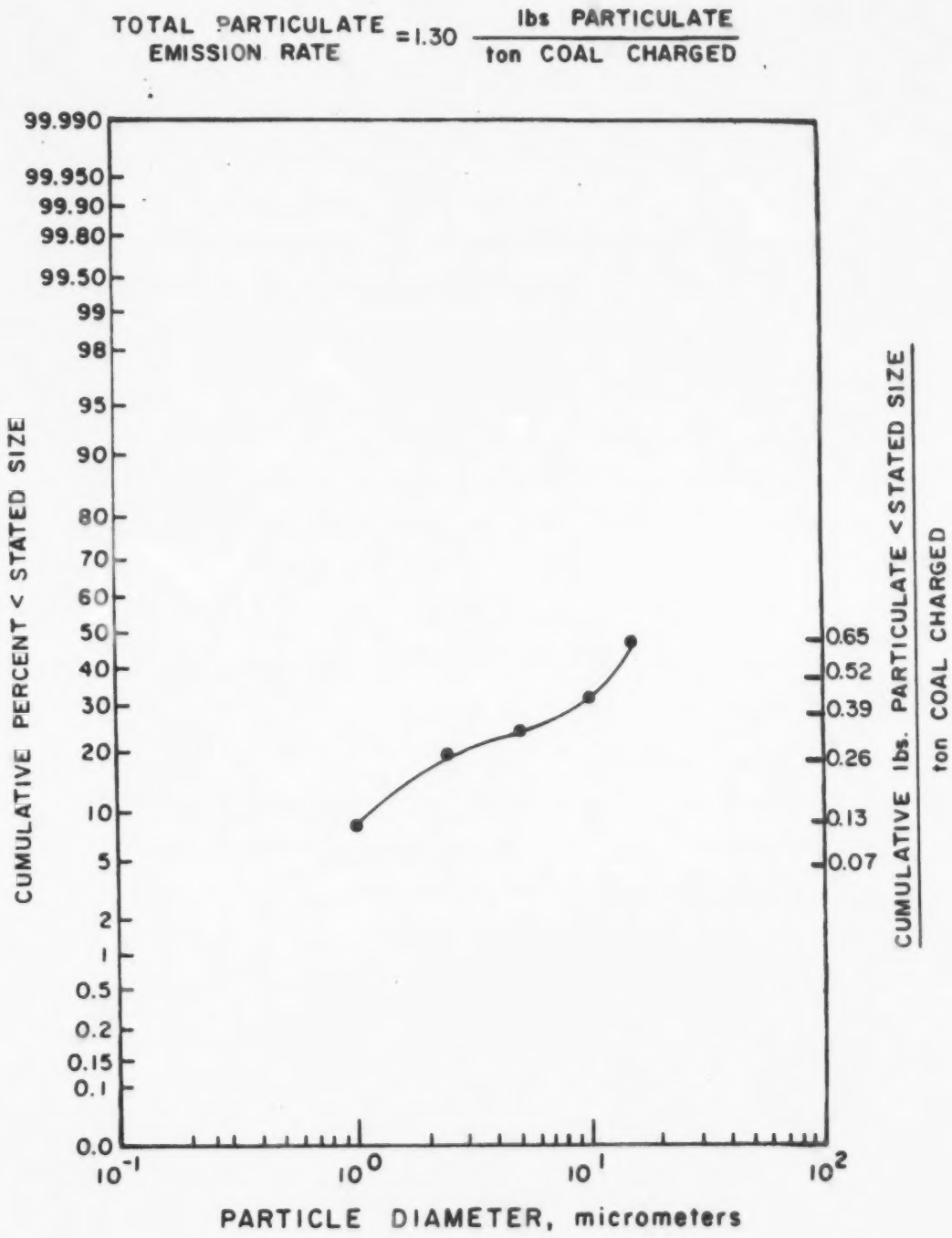


Figure 7.2-11. Quenching (controlled with baffles) dirty water >5,000 mg/L TDS.

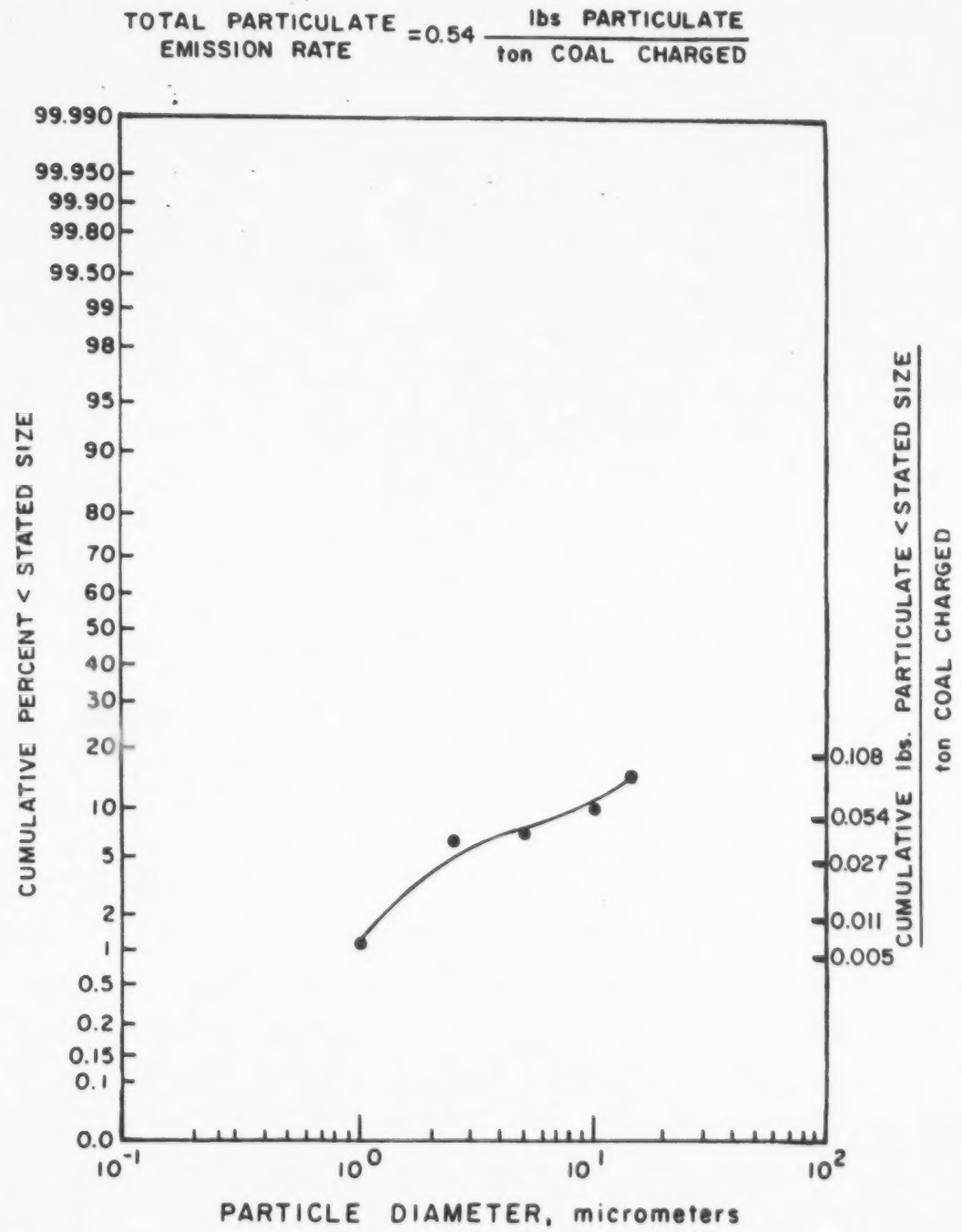
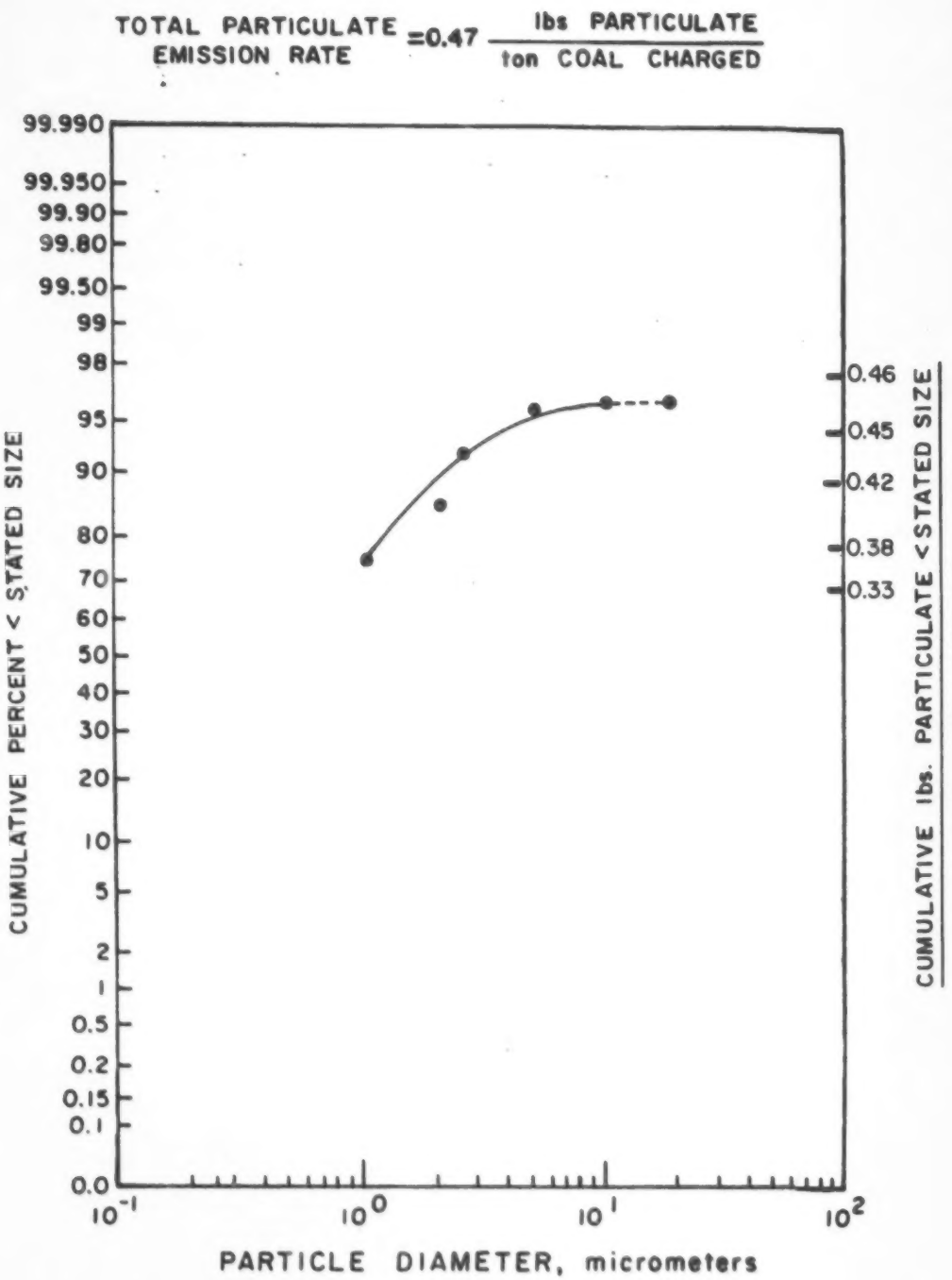


Figure 7.2-12. Quenching (controlled with baffles) clean water <1,500 mg/L TDS.



Note: Extrapolated to the 15 μm size, using engineering estimates.

Figure 7.2-13. Combustion stacks (uncontrolled) average of 3 sites.

References for Section 7.2

1. John Fitzgerald, et al., Metallurgical Coke Industry Particulate Emissions: Source Category Report, EPA-600/7-86-050, U.S. EPA, Research Triangle Park, NC, December 1986.

2. Air Pollution By Coking Plants, United Nations Report: Economic Commission for Europe, ST/ECE/Coal/26, 1968.

3. R. W. Fullerton, "Impingement Baffles To Reduce Emissions from Coke Quenching", Journal of the Air Pollution Control Association, 17:807-809, December 1967.

4. J. Varga, Jr., and H. W. Lownie, Jr., Final Technological Report On A Systems Analysis Study Of The Integrated Iron And Steel Industry, EPA Report APTD 1279, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1969.

5. Particulate Emissions Factors Applicable To The Iron And Steel Industry, EPA-450/4-79-028, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1979.

6. Stack Test Report for J & L Steel, Aliquippa Works, Betz Environmental Engineers, Plymouth Meeting, PA, April 1977.

7. R. W. Bee, et al., Coke Oven Charging Emission Control Test Program, Volume 1, EPA-650/2-74-062, U. S. Environmental Protection Agency, Washington, DC, July 1974.

8. Emission Testing And Evaluation Of Ford/Koppers Coke Pushing Control System, Volume 2, Appendices, EPA-600/2-77-187b, U. S. Environmental Protection Agency, Washington, DC, September 1977.

9. Stack Test Report, Bethlehem Steel, Burns Harbor, IN, Bethlehem Steel, Bethlehem, PA, September 1974.

10. Stack Test Report for Inland Steel Corporation, East Chicago, IN Works, Betz Environmental Engineers, Pittsburgh, PA, June 1976.

11. Stack Test Report for Great Lakes Carbon Corporation, St. Louis, MO, Clayton Environmental Services, Southfield, MO, April 1975.

12. Source Testing Of A Stationary Coke Side Enclosure, Bethlehem Steel, Burns Harbor Plant, EPA-340/1-76-012, U. S. Environmental Protection Agency, Washington, DC, May 1977.

13. Stack Test Report for Allied Chemical Corporation, Ashland, KY, York Research Corporation, Stamford, CT, April 1979.

14. Stack Test Report, Republic Steel Company, Cleveland, OH, Republic Steel, Cleveland, OH, November 1979.

15. J. Jeffrey, Wet Coke Quench Tower Emission Factor Development, Dofasco, Ltd., EPA-600/X-85-340, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1982.

16. Stack Test Report for Shenango Steel, Inc., Neville Island, PA, Betz Environmental Engineers, Plymouth Meeting, PA, July 1976.

17. Stack Test Report for J & L Steel Corporation, Pittsburgh, PA, Mostardi-Platt Associates, Bensenville, IL, June 1980.

18. Stack Test Report for J & L Steel Corporation, Pittsburgh, PA, Wheelabrator Frye, Inc., Pittsburgh, PA, April 1980.

19. R. B. Jacko, et al., By-product Coke Oven Pushing Operation: Total And Trace Metal Particulate Emissions, Purdue University, West Lafayette, IN, June 27, 1976.

20. Control Techniques For Lead Air Emissions, EPA-450/2-77-012, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.